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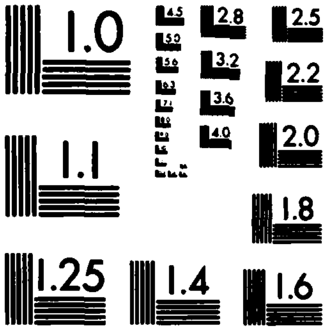

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THERMOSPHERE STRUCTURE VARIATIONS DURING
HIGH SOLAR AND MAGNETIC ACTIVITY CONDITIONS

Jeffrey M. Forbes

Boston College
Chestnut Hill, MA 02167

AD-A171 350

30 September 1985

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8 March 1982 - 30 September 1985

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AIR FORCE GEOPHYSICS LABORATORY
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"This technical report has been reviewed and is approved for publication"

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Laboratory Contract Manager

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FOR THE COMMANDER

ROBERT A. McCLATCHEY
Director, Atmospheric Sciences Division

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Analyses of satellite accelerometer and rocket grenade and pitot-tube data are performed to delineate the seasonal-latitudinal variability of temperature and density between 80 and 120 km, and the latitude-time dependence of temperature, density, and wind variability at satellite attitudes during geomagnetically-disturbed conditions. A two-cell pattern of neutral winds is inferred from the satellite data that intensifies and expands spatially in response to increased magnetic activity. Density variations during magnetically active conditions are characterized by density bulges and troughs, some of which remain quasi-stationary at high latitudes, and others which suggest wave propagation towards the equator. Monthly tabulations every 15° latitude of temperature, density, and pressure up to 120 km are provided which merge smoothly with the Air Force Reference Atmosphere in the 70-80 km height regime. Theoretical calculations are utilized to provide estimates of tidal variability about the mean values contained in the tables.

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1. MAGNETIC STORM VARIATIONS IN THERMOSPHERIC DENSITIES, TEMPERATURES, AND WINDS

At the NOAA "Workshop on Satellite Drag," March 18-19, 1982, Boulder, Colorado, a paper entitled "Geomagnetic Storm Variations and Prediction of Low-Perigee Satellite Ephemerides" by J.M. Forbes was presented. A written version has appeared in the proceedings of the workshop. In this paper, the spatial/temporal characteristics of density perturbations in the lower thermosphere (150-250Km) during geomagnetic disturbances are discussed within the context of the low-perigee satellite ephemeris prediction problem. The variability of atmospheric density (satellite drag) is significantly enhanced at high latitudes due to the proximity of magnetosphere/ionosphere source mechanisms for the neutral atmosphere disturbances. In addition, for precise orbital computations winds in excess of about $300msec^{-1}$(which commonly occur at high latitudes) must also be considered as part of the drag effect. It is demostrated that precise low-perigee ephemeris predictions require accurate forecasting of the phase as well as spatial structures of atmospheric density and wind disturbances. It was recommended that future advances in predictive capability of atmospheric drag necessitate (1) Comprehensive numerical modelling efforts which tie together all of the relevant

high-latitude processes in a self-consistent manner, and which can be utilized to provide insight into the development of an improved magnetic index of density variations, and guide the development of semi-empirical models for predicting stellite drag variations; and (2) Concerted experimental efforts to obtain simultaneous drag and electrodynamic data (incoherent scatter measurements of temperature and drifts; satellite measurements of particles, fields and currents; and ground magnetometer measurements).

Dr. Forbes and Mr. J. Slowey attended a Technical Interface Meeting at AFSCF, Sunnyvale, CA on 26-27 April 1982, which was held for the purpose of coordinating AFSCF's Data System Modernization (DSM) efforts with its prime contractor, IBM. A point of discussion concerned the Jacchia-Roberts analytic model, which was originally fitted to the J70 model, whereas a second version of the model was developed by IBM which was fitted to the J71 model. J. Slowey recommended that the version of the Jacchia-Roberts model fitted to the J70 model be retained in the system, but that equations representing low altitude geomagnetic activity in the J71 be substituted for those in the J70 model. Dr. Forbes gave some reasons why it would not be advisable to add the MSIS-77 model to their system at this time. These included:

(a) The MSIS represents a fit to composition and temperature measurements, not total mass densities;

(b) Data utilized to construct MSIS covers a limited range of solar activity and altitude, as compared to the Jacchia models;

(c) The geomagnetic effect in MSIS-77 is parameterized by the daily Ap index, which is incapable of reflecting time variability as well as the 3-hour Kp index utilized in the Jacchia models;

(d) MSIS-77 requires about 25% more CPU time that J71; and

(e) The Millstone Hill (MH) temperatures used in MSIS-77 originated from the 1-pulse experiment at MH, which contain a 50K bias (based on more accurate 2-pulse data analyzed since development of MSIS-77.).

Dr. Forbes also presented comparisons of prediction errors for various models and satellite orbits which have been examined over the years within AFGL. In particular, the Harris-Priester Model, which was discussed for possible consideration by SCF and IBM as part of DSM was shown to exhibit considerably larger prediction errors and about twice the CPU time than J71.

Dr. Forbes and A. Kantor of AFGL attended a meeting of the DARPA Committee for Autonomous Positioning of GPS at Hq ONR on May 1982. At this meeting possible satellites, in

addition to GPS, for which the SHAD (Stellar Horizon Atmospheric Dispersion) navigation system could be used were discussed. Some of these satellites are classified. Density variability in the 20-50Km altitude region could provide a limitation to the navigation accuracy. A. Kantor discussed his planned study of day-to-day and seasonal variabilities, including the statistical quantities to be provided, and Dr. Forbes presented his plans to provide information on the tidal variations. In addition, in response to Dr. F. Quelle's (ONR) request for possible science that could be derived from the SHAD experiment, Dr. Forbes offered a number of suggestions, falling within the following scientific areas:

(a) Global Climatology

(b) Polar Stratospheric Warmings

(c) Planetary-Scale Waves

(d) Equatorial Waves

(e) Mesospheric Particulate Layers

(f) Minor Constituents

which were subsequently incorporated with other recommendations into a letter from Dr. Champion to Dr. Quelle.

During 1982 the capability was developed to derive neutral thermospheric temperatures from ionospheric

parameters (Te, Ti, Ne) measured by incoherent scatter radars at Millstone Hill (42^{o}) and Arecibo (18^{o}N). The purpose of this project was to examine the equatorward propagation and extension of high-latitude geomagnetic disturbance effects. To develop the above capability involved the following tasks:

(1) Acquisition of the following magnetic tapes of Arecibo data from the World Data Center:

  (a) I9/I29 (August 1974 - May 1977)

  (b) N35 (December 1971 - December 1972)

  (c) N12 (July 1966 - December 1970)

  The tapes initially acquired contained formatting errors and additional problems. After extensive attempts at analysis and conversations with the World Data Center, reformatted tapes were acquired and subsequently analyzed.

(2) Development of programs to read and plot Te, Ti, and Ne off acquired tapes. A sample plot is illustrated in Figure 1. For every set of vertical profile measurements (available on the order of every 15 minutes) of Te, Ti and Ne, a determination had to be made of the quality and acceptability of the data for further analysis. Sometimes instrument or power

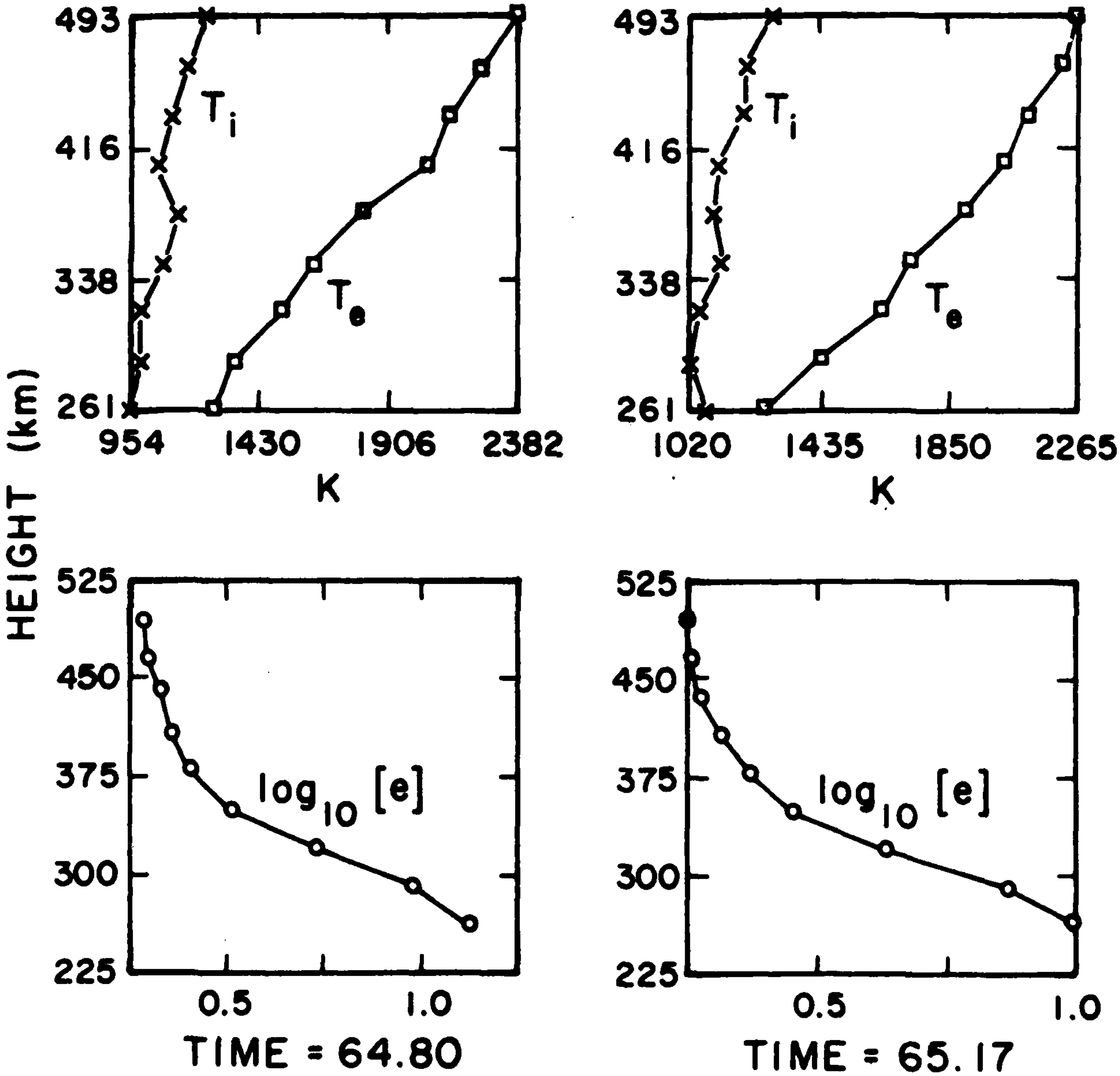

Figure 1. Sample vertical profiles of ionospheric parameters derived from Arecibo incoherent scatter measurements on day 260 of 1974.

problems suggested the rejection of data. Occasionally, unrealistic or inexplicable observations (for instance Ti > Te) had to be rejected. The editing of Te, Ti and Ne data prior to neutral temperature determinations (see following paragraph) is a tedious step in the analysis.

(3) Acquisition of NEUTEMP program from Dr. W. Oliver of Millstone Hill and program redevelopment for use on the AFGL CDC machine for calculation of Tn. The Millstone Hill facility uses a Harris computer. The NEUTEMP program iteratively solves the ion thermal balance equation (given Te, Ti, Ne) to produce neutral thermospheric (exospheric) temperatures.

(4) Tailoring of the Multiple Linear Regression Analysis (MLRA) Program and development of plotting package for Millstone Hill neutral exospheric temperature analysis on the CDC machine.

The first Arecibo experiment analyzed, and the one used to develop and test the above programs, is day 260 of 1974. This day was characterized by an F10.7 value of 89 and a daily magnetic Ap index of 3 (Kp less that 2- throughout the day). The neutral exospheric temperatures obtained are illustrated in the lefthand portion of Figure 2. The MLRA yielded the following Fourier components: mean = 842K,

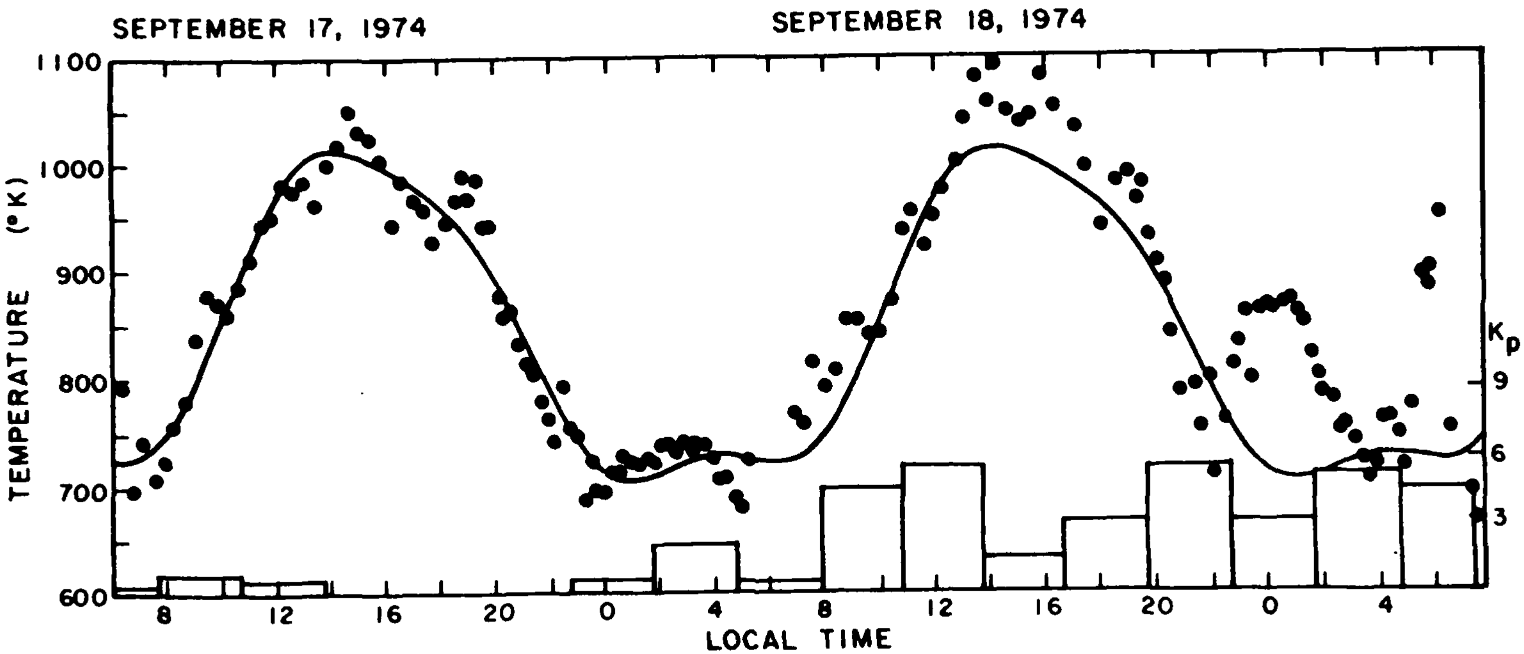

Figure 2. Neutral exospheric temperatures (dots) during September 17-18, 1974 at Arecibo. Solid line represents fit to quiet-day (September 17) values. Kp values are also shown. Note the increase in geomagnetic activity between the first and second days.

diurnal = 158K, semidiurnal = 24K, and terdiurnal = 22K. Local times of maxima were: diurnal = (15.2), semidiurnal = (3.0, 15.0) and terdiurnal = (4.0, 12.0, 20.0). The following day (September 18) was characterized by significant geomagnetic activity, with Kp values of up to 5+. The quiet-day least-squares fit was extrapolated into the second day to delineate the different temperature response during the magnetically disturbed period (See Figure 2). Temperature differences from the quiet-day behavior in the range of 100-200K are clearly evident.

Exospheric temperatures were also derived from incoherent scatter data at Millstone Hill (42^{o}N) during the geomagnetically disturbed (Kp < 5o) day of June 3, 1971. A magnetically quiet day (Kp < 2-; F10.7 = 108.3) with similar F10.7 was also analyzed as a reference day. Unfortunately, the quiet-day data contained strong oscillations suggesting the presence of gravity waves, rendering questionable the use of a fit to these data as a quiet-day reference. Therefore, the separation of the magnetic storm contribution from the June 3, 1971 data was not possible.

The next step in the incoherent scatter project was to have been the analysis of several storms simultaneously observed at Millstone Hill and Arecibo during the solar maximum period 1979-1981. However, besides the March 22, 1979, storm to be described below in conjunction with the

analysis of satellite accelerometer-measured densities, this effort was never completed. The reasons for this were twofold. First, initial postponement of the effort occurred due to the higher priority given to the interpretation of satellite winds and densities during geomagnetically active periods, as described below. Then, approximately simultaneous with the principal investigator moving to Boston University, a new and unanticipated effort relating to the analysis of data and development of inputs to the Air Force Reference Atmosphere in the 80-120Km height region was given first priority by the Air Force. The subsequent subcontract to Dr. Forbes at Boston University only provided for (a) the 80-120Km region data analysis and (b) satellite density and wind analysis during magnetically disturbed conditions, and did not fund completion of the incoherent scatter work. Work completed under item (b) is reported below and the results of (a) are included in Section 3.

The work involving analysis and interpretation of satellite accelerometer-measured densities and winds under geomagnetically- disturbed conditions is reported fully in the following publications:

Marcos, F.A., and J.M. Forbes, Thermospheric Winds from the Satellite Electrostatic Triaxial Accelerometer System, J. Geophys. Res., 90, 6543-6552, 1985.

Forbes, J.M., and F.A. Marcos, Thermospheric Winds, Densities, and Temperatures during an Isolated Magnetic Storm. (CDAW-6 Interval), J. Geophys. Res., accepted for publication, manuscript in revision, 1985.

In the first paper a new thermospheric wind measurement technique is reported which is based on a Satellite Electrostatic Triaxial Accelerometer (SETA) System capable of accurately measuring accelerations in the satellite's in-track, cross-track, and radial directions. Winds measured between 170 and 210 Km during a 5-day period of mostly high geomagnetic activity are analyzed to demonstrate the potential contributions of SETA data to studies of thermospheric dynamics. The data are consistent with a two-cell polar circulation pattern characterized by a trans-polar flow parallel to the 1600 h/0400 h geomagnetic local time meridian, and return flows in the late morning and late evening sectors. The flow pattern was found to be asymmetric in that it is displaced about 5-10^{o} latitude towards the noon (MLT) sector, and the evening cell is somewhat more diffuse than the morning cell. The system also covers a greater area of the polar cap and is more intense during active (Kp > 5^{o}) than quiet (Kp 3^{o}) geomagnetic conditions. Average trans-polar flow velocities are characteristically of order 150 ± 75 $ms^{-1}$for Kp ~~ 2^{o} and 375 ± 100 ms-1for Kp ~~ 5^{o}, the stated variabilities

representing 1σ deviations. Details may be found in the above-cited publication.

In the second work, thermospheric winds and densities form SETA (Satellite Electrostatic Triaxial Accelerometer) measurements and exospheric temperatures form Millstone Hill incoherent scatter radar data are examined during an isolated magnetic storm occurring on March 22, 1979, a period which coincides with the CDAW-6 interval. A polar thermospheric wind circulation suggestive of a two-cell horizontal convection pattern is reflected in the cross-track acceleration measurements. Winds are generally trans-polar and appear to flow parallel to the 1600h/0400 MLT meridian with return flows in the morning and evening sectors near $57.5^{\circ} \pm 7.5^{\circ}$ and $70^{\circ} \pm 7.5^{\circ}$ geomagnetic latitude, respectively. Winds are of order 100-200 ms^{-1}control during quiet periods, and attain maximum speeds between 300 and 600 ms^{-1}during the storm. The two-cell pattern is distinctively more well-ordered in geomagnetic rather than geographic coordinates. The time delay between maximum magnetic disturbance as reflected by the 3-hour ap index and full set-up of the circulation pattern is somewhere between 0-3 hours, the uncertainty being due to the discrete nature of ap and the 90-minute orbital period. The circulation pattern persists almost unattenuated for about 6 hours after

the magnetic disturbance has returned to quiet levels, reflecting the so-called 'flywheel' effect.

The density response is highly asymmetric with respect to its day/night behavior. At high geomagnetic latitudes (> 60^{o}) the daytime density variation, about a 40% increase form quiet levels, distinctively reflects the response to an increase in magnetic activity with a time delay of less than 3 hours. At lower latitudes the response is smaller (~~20%) and less well-defined, occuring with time delay of about 6 $\pm$ 2 hours near $10-20^{o}$ latitude. The nighttime density response, on the other hand, is not so well defined poleward as it is equatorward of 60^{o} latitude. The time delay increases from about 2 $\pm$ 2 hours to 6 $\pm$ 2 hours from high to low latitudes.

An exospheric temperature response occurs at Millstone Hill (42^{o}N) with an amplitude of 210 K and time delay of between 0 and 2.5 hours.

Latitude structures of the density response at successive times following the substorm peak suggest the equatorward propagation of a disturbance with a phase speed of between 300 and 600 ms-1. A deep depression in the density at high latitudes (>70^{o}) is evident in conjunction with this phenomenon. The more efficient propagation of the disturbance to lower latitudes during the night may be connected with the 'midnight surge' effect, a reinforcement

of southward winds associated with high latitude heating and solar EUV heating, as opposed to cancellations between these meridional flows during the daytime. Details of this study may be found in the above-cited manuscript.

2. ATMOSPHERIC TIDES STUDIES

Atmospheric tides constitute much of the meteorology and variability in atmospheric fields above 70 Km altitude, and as such represent a major uncertainty in specifying environmental conditions for a variety of Air Force missions. Experimental data often suffer from inadequate coverage in local time and/or latitude to properly delineate tidal motions, so greater reliance on theory and numerical simulations must be made in this discipline of study. The following work was performed to better understand the nature of tidal oscillations and the uncertainty which they contribute to density and temperature specifications in the upper atmosphere.

A paper entitled "Neutral Temperatures from Thompson Scatter Measurements: Comparisons with the CIRA (1972)" by J. M. Forbes, M. E. Hagan, and K. S. W. Champion was prepared for presentation at the COSPAR Meeting, Ottowa, Canada, May, 1982, and was published in Space Research, Volume 3, 1983. In this paper, Neutral exospheric and lower thermospheric (100-130 km) temperatures from Thomson scatter measurements

at Millstone Hill (42^{o}N) are compared with CIRA temperatures with a view towards identifying deficiencies in the CIRA and recommending revisions. CIRA is found to model the observed diurnal mean temperatures (T_o) to within 10% over a wide range of solar conditions (75< F10.7< 250), but consistently underestimates the diurnal temperatures with maximum deviations approaching 50% of observed amplitudes (180-240 K) at solar maximum (1200 K $\leq T_o \leq$ 1400 K). The observed semidiurnal amplitudes, which lie in the range of 20K-80K, are always underestimated and frequently by more than 50%. In the lower thermosphere, tidal oscillations of temperature of order 20K-40K occur which are not modelled by CIRA. In addition, an analysis of exospheric temperatures at Millstone Hill during a magnetic disturbance indicates a response within 1-2 hours from storm onset, whereas CIRA assumes a 6.7 hour delay. As a result, and although some of these deficiences are addressed by the more recent MSIS model, there exists a sufficient data base to recommend several additional revisions to the CIRA temperatures at this time.

A review of thermosphere tides was prepared as AFGL Report TR-82-0264 entitled "Tides in the Thermosphere: A Review" by J.M. Forbes and K.S.W. Champion. In it a comprehensive review of recent theoretical and observational accomplishments relating to diurnal and semidiurnal tidal

oscillations of neutral winds, temperature, density, and composition above 100 Km is presented. Topics emphasized include: (1) Recent theoretical studies; (2) Solar cycle, seasonal, and latitudinal variations in tidal oscillations of temperature and winds as inferred from Thomson scatter measurements; (3) Tidal variations in total mass density and composition as inferred from satellite accelerometer and mass spectrometer measurements; (4) Comparison of recent theoretical models with the above observations; (5) The relative influence of in-situ and propagating tides in determining the total semidiurnal thermospheric tide; and (6) Propagating tides of lower atmosphere origin as a source of mean momentum and heat in the lower thermosphere.

As an input to the SHAD (Stellar Horizon Atmospheric Dispersion) Program, a draft report was written by Dr. Forbes entitled "Density Variability due to Atmospheric Tides below 140 Km". In this report equations and a computer algorithm were derived for the tidal oscillations in density compatible with temperatures from the numerical tidal model of Forbes. Vertical profiles and tables of tidal amplitude and phase corresponding to 0°, 30°, and 60° latitude under equinox conditions were included for the diurnal and semidiurnal components, respectively. Diurnal amplitudes were found to be of order 1-2% in the stratopause region (ca. 50 km) and 5-15% in the mesopause region, attaining

amplitudes of 7-25% near 110 Km where the first diurnal propagating (1,1) mode begins to experience severe molecular dissipation. The phase structure at 0^{o} and 30^{o} latitude in fact revealed a nominal 25-30 Km vertical wavelength characteristic of the (1,1) mode. A constancy of phase with height above 50 Km for latitudes >~ 30^{o} was noted to be indicative of the trapped (1,-2) tidal mode.

The semidiurnal oscillations were found to be significantly smaller than the diurnal component below 100 Km, of order .2-1% around the stratopause and 2-6% in the mesopause region. Amplitudes of 20-25% are attained in the vicinity of 120 Km. Semidiurnal vertical wavelengths below 70 Km are much larger than for the diurnal tide, characteristic of the fundamental (2,2) mode. Above 80 Km the presence of the shorter-wavelength (2,4) mode is evident, due primarily to mode coupling processes involving the mean zonal wind and meridional temperature gradient distributions.

Over most of the 0-140 Km altitude regime the largest density perturbations generally occur at equatorial latitudes for the diurnal and semidiurnal tides. However, considerable latitude structure is exhibited at any given level. A discussion was also included of the possible effect of non-migrating tidal components. (i.e., those which do not migrate with the apparent motion of the sun). It was noted that wind data from the Jicamarca, Peru (12^{o}s) incoherent

scatter radar indicate the presence of non-migrating components with amplitudes as much as an order of magnitude larger than the migrating contribution. Thus the potential exists (at least at some longitudes) of significantly larger tidal density variations in the low-latitude stratosphere than given for the migrating components. It was recommended that SHAD density data from the HEAO experiment, and in the possession of the MIT Draper Laboratories, should be able to reveal non-migrating tidal components in stratospheric density if they exist.

The density work was subsequently expanded upon to provide inputs to the point-analysis and Air Force Reference Atmosphere efforts, and was written up in as a proposed AFGL report entitled "Estimates of Point-Density Errors due to Atmospheric Tides between 70 and 120 Km" by J.M. Forbes. This latter report includes various contours of "percent density departures from mean values due to tides" as a function of height, latitude, local time and season.

3. TEMPERATURES, PRESSURES, AND DENSITIES IN THE 80-120 Km REGION

3.1 Introduction

At the present time the standard reference for temperature, density, and wind specification between 80 and

120 Km is the 1972 COSPAR International Reference Atmosphere (CIRA 1972). Temperatures and densities are given as monthly averages at 5 Km height increments every 10° in latitude for the Northern Hemisphere. However, data are extremely sparse in this region; as Groves (see CIRA 1972) points out, CIRA 1972 suffers from the same limitations as CIRA 1965 above 60 Km:

(i) Data from all longitudes are combined without consideration of longitudinal effects. Most data are from N. American sites, and so any longitudinal bias would be towards the W. Hemisphere.

(ii) Insufficient S. Hemisphere data were available for developing a separate model. Therefore, S. Hemisphere data were combined with N. Hemisphere data with a six-month change of date.

(iii) Due to insufficient data, no account was taken of local time in development of the models. Consequently the temperature and density fields may be diurnally-biased as well.

The current Air Force Reference Atmosphere (Cole and Kantor, 1978) only extends to 90Km. Development of the temperature and density inputs between 80 and 120 Km for the new Air Force Reference Atmosphere (AFRA) has involved building upon the existing CIRA 1972 model data base (see section 3.2). Since the greatest abundance of experimental data is in the form of temperatures, and since temperature is one of the meteorologial fields (besides winds) for which we have a firmer theoretical and intuitive base for understanding its behavior and structure, the temperature field is the basis for development of the model. Following the procedure

followed in CIRA, given a specification of the pressure field at some lower boundary, the density field at higher altitudes were derived from the barometric and ideal gas laws. Available experimental density determinations are used to provide consistency checks on these densities. A preliminary analysis of this data was written up in the form of a report "Temperature Structure of the 80 to 120Km Region" by J.M. Forbes, as input to the COSPAR working Group on the new Cospar International Reference Atmosphere. The report has been published in the MAP Handbook Series, Volume XVI.

3.2. Description of the Temperature Data Base

The following is a description of the data which has formed the basis for the 80-120 Km specification of temperature, density and pressure recommended for the new AFRA:

(i) The CIRA 1972 temperature model between 80 and 120 Km was based heavily on data from the NASA Meteorological Sounding Rocket Program (MSRP) collected prior to 1967. The primary techniques were pitot tube and grenade measurements. The MSRP was phased out in 1973. Between 1967 and 1973 32 pitot tube and 135 rocket grenade experiments were conducted which generally yielded temperature data

above 80Km. The soundings were made at Wallops I. (38^{o}N, 75^{o}W), Ft. Churchill (59^{o}N, 94^{o}W), Pt. Barrow (71^{o}N, 157^{o}W), Natal (6^{o}S, 35^{o}W), Arecibo (18^{o}N, 67^{o}W), Arenosillo (37^{o}N), Eglin (30^{o}, 87^{o}W), and Kourou (5^{o}N, 53^{o}W) (Smith et al, 1967, 1968, 1969, 1970, 1971).

(ii) Gaigerov et al(1984) present extensive analyses of temperatures from Soviet rocket measurements (mostly grenade method) north and south of the equator in the Eastern Hemisphere. Most of the Southern Hemisphere data were collected after 1970, and hence were not included in the 1972 CIRA. Gaigerov et al also discuss the results of several intercomparisons with other independent measurements of temperature, and report that adjustments have been made for any biases which might have existed in their raw data. Monthly average data between 80 and 90-100Km are available from Heiss I. (81^{o}N, 58^{o}E), Volgograd (48^{o}N, 44^{o}E), Molodezhnaya (68^{o}S, 45^{o}E), and from research vessel soundings in the Pacific near 0^{o}, 20^{o}S, 40^{o}S, and 50^{o}S. Keeping in mind known deficiencies in the Soviet data, this information

now enables us to examine possible longitudinal and latitudinal asymmetries in the structure of the mesopause region. S. Hemisphere data may in fact introduce an undesired bias in the AFRA if mixed with N. Hemisphere data, and so this aspect of the analysis has been pursued with caution.

(iii) Five years (1970-1975) of temperature profiles from incoherent scatter measurements in the E-region (100-130Km) over Arecibo, Puerto Rico (18^{O}N, 67^{O}W) and Millstone Hill, Massachusetts (42^{O}N, 71^{O}W) were available for analysis. These data have been analyzed in parts, mostly with regard to the semidiurnal oscillation by Salah (1974), Salah et al (1975), Salah and Wand (1974), and Wand (1976, 1983). This investigator has pooled all the available data, separated mean and semidiurnal tidal components, and constructed monthly averages. A total of over 1,500 profiles (each) are available from Arecibo and Millstone Hill. These data are considered extremely important in terms of "matching" the rocket-based temperature structure of the 80-100Km region with the satellite-based density and temperature fields above 150Km.

A list of stations from which rocket and radar data has originated for the new AFRA is included in Table I. A preliminary analysis was first performed to ascertain whether evidence exists for longitudinal and latitudinal asymmetries in the temperature structure of the 80Km to 100Km region, and whether sufficient data are available to delineate these dependences in a reference atmosphere.

TABLE I

Locations of rocket* measurements and incoherent scatter radar** measurements which form the basis data for the new AFRA between 80Km and 120Km.

	"Western Hemisphere"		"Eastern Hemisphere"	
	Thule	(76°N, 69°W)	Heiss I.	(81°N, 58°E)
	Pt. Barrow	(71°N, 157°W)	Volgograd	(48°N, 44°E)
	Ft. Churchill	(59°N, 94°W)	Sardinia	(40°N, 10°E)
**	Millstone Hill	(42°N, 71°W)	Guam	(13°N,145°E)
	Wallops I.	(38°N, 75°W)	Kwajalein	(9°N,168°E)
	White Sands	(32°N, 106°W)	Thumba	(8°N, 77°E)
	Eglin	(30°N, 87°W)	Res. Vessels	(0°)
	Cape Kennedy	(28°N, 80°W)	Res. Vessels	(20°)
	Barking Sands	(22°N, 159°W)	Carnavon	(25°S,114°E)
**	Arecibo	(18°N, 67°W)	Woomera	(31°S,136°E)
	Antigua	(17°N, 62°W)	Res. Vessels	(50°S)
	Ft. Sherman	(9°N, 80°W)	Kerguelen I.	(49°S)
	Kourou	(5°N, 53°W)	Res. Vessels	(50°)
	Natal	(6°S, 35°W)	Molodezhnaya	(68°S, 45°E)
	Ascension I.	(8°S, 14°W)		

* With some exceptions, data are generally available between 80-100Km

** Data generally available between 100-130Km

In Figure 3 variations in monthly temperatures at 85Km for individual stations are compared. The comparison between Pt. Barrow (71^{o}N, 157^{o}W) and Heiss I. (81^{o}N, 58^{o}E) suggests 5-10^{o}K higher temperatures at Heiss I. in the summer and 5-10^{o} cooler temperatures between January and March. Although these two stations are separated by 10^{o} in latitude, the discrepancy is opposite to what one might expect from the positive (negative) pole-to-equator temperature gradient assumed to exist in Northern Hemisphere summer (winter) months. An examination of vertical structures at the two stations indicates that the summer mesopause minimum is near 90Km at Heiss I. as opposed to 85Km at Pt. Barrow, and this is in itself is an important contributor to their differences in monthly behavior at 85Km.

Although the Volgograd (48o$_{N,}$ 44^{o}E) data during summer exhibit 10-15^{o}K higher temperatures that Ft. Churchill (59^{o}N, 94^{o}W), their 11^{o} separation in latitude is sufficient to account for more than half of this difference assuming a realistic latitude gradient in temperature (see following figures). Figure 3 also suggests a much larger temperature gradient in the eastern than western hemisphere, but it must be remembered that Ft. Churchill and Pt. Barrow are only separated by 12^{o} latitude, whereas the separation between Heiss I. and Volgorad is 33o in latitude. Obviously, to make any

convincing statements about latitude structure we should examine all possible data at a given height. This will be done below. Before leaving Figure 3, note that Southern Hemisphere data at 40°S and 50° agree quite well with the Northern Hemisphere data at similar latitudes.

In Figures 4 and 5 the latitude structures of temperature during summer (mostly July) and winter (mostly January), respectively, are depicted at 80, 90, and 100Km. An obvious feature of these plots is that the Eastern/Western/Northern/Southern Hemisphere data collectively delineate fairly well-defined patterns.

Figure 6 depicts a selection of temperature measurements between 100 and 130Km at various latitudes during July and January. Comparisons are made with the MSIS-83 model (Hedin et al, 1983), as this is a likely candidate for the new AFRA above 100Km or so. The data shown in Figure 6 during January are extremely consistent with each other and with the MSIS-83 model, and do not exhibit any significant latitude structure. During July, however, there appears to exist a significant positive equator-to-pole temperature gradient. At 115Km, the temperature varies from about 268°K at Kwajalein (9°N) to 320°K at Arecibo (18°N) to 370°K at Wallops I. (38°N) and Millstone Hill (42°N). A small temperature difference (20°K) of this sense between 18°N and 42°N is specified in the MSIS-83 model. Compared with the earlier AFRA, the present data set provides improved

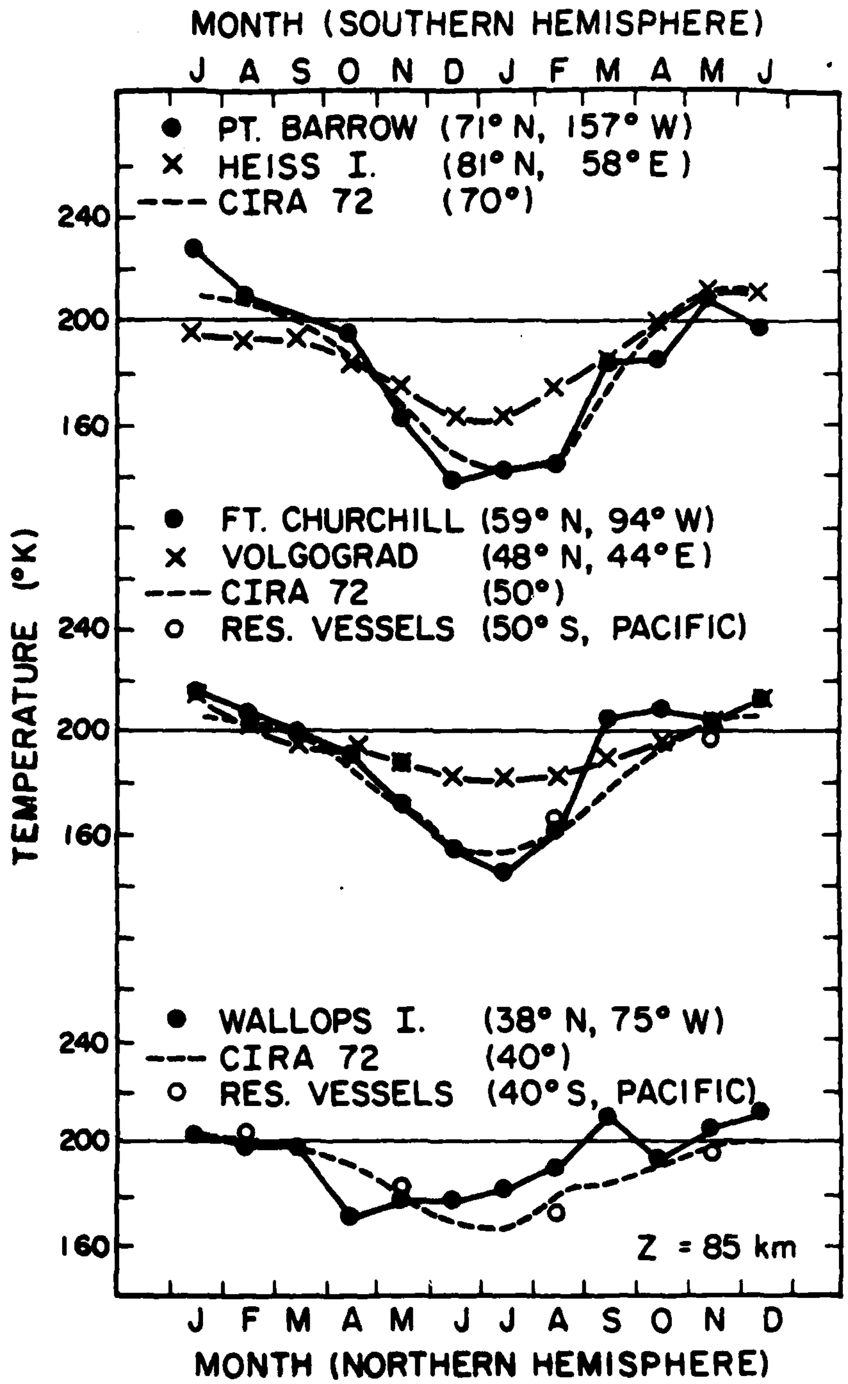

Figure 3. Temperature vs. month at 85Km for various stations which allow examination of possible longitudinal or hemispherical asymmetries within specific latitude belts. CIRA 1972 values are shown for comparison.

seasonal, latitudinal, and longitudinal coverage in the 80-100Km region, and a combination of incoherent scatter and rocket data in the 100-120Km region which allows a much improved delineation of lower thermosphere temperature structure. At the same time, although some individual station comparisons indicate measurable asymmetries in longitude and latitude, data are still insufficient to separate these effects; that is, to provide a reliable description of latitude structure as a function of longitude, or of longitude structure at any given latitude. It is therefore recommended that in order to obtain the best description of Northern Hemisphere temperatures, pressures, and densities between 80 and 120Km, one must combine together data from all longitudes and from the Southern Hemisphere (with a 6-month change of date) in order to obtain even a minimally acceptable distribution of data. Thus the AFRA model input as it is provided here is not capable of distinguishing longitudinal or hemispheric dependences if they exist. Soviet data (which has been bias-corrected) has also been included in the data set. Inclusion of Southern Hemisphere and/or Soviet data may arouse some concern. As it turns out, both of these data show remarkable consistency with the North American data, and in some cases fill crucial gaps or extend the data set and model credibility to higher latitudes than would otherwise be unattainable. High

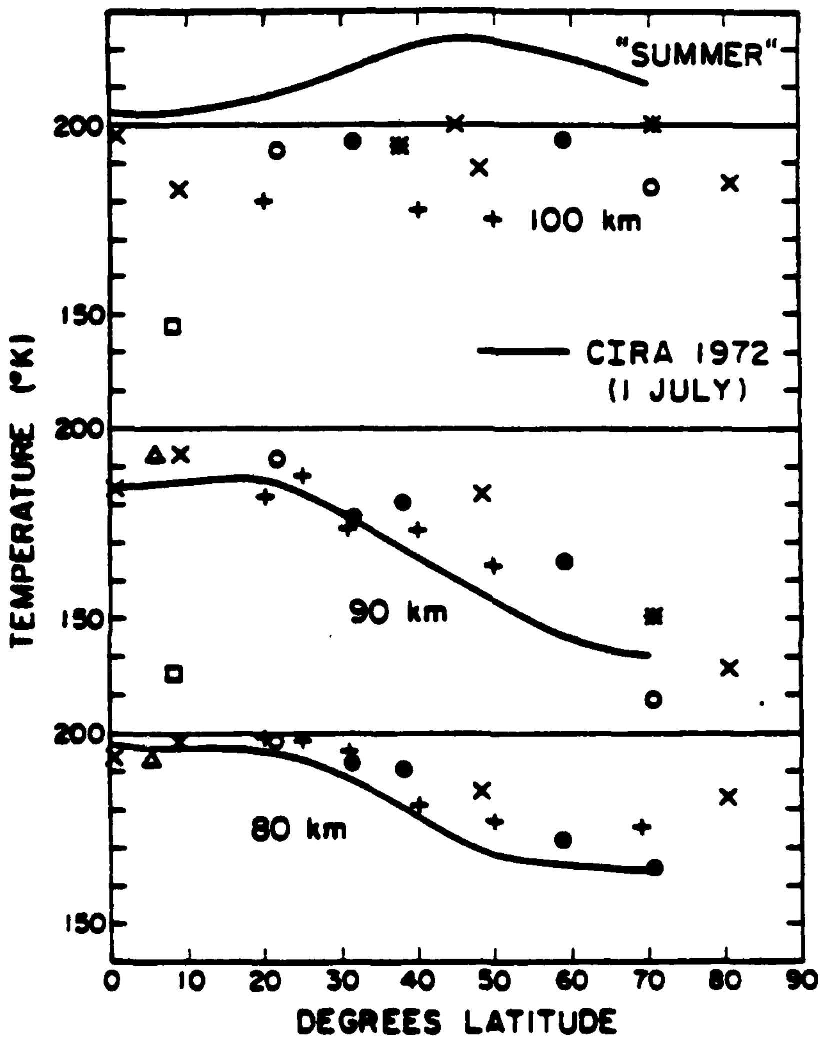

Figure 4. Temperature vs. latitude for measurements representative of July north of the equator in the Western (●) and Eastern (✕) Hemispheres, and January south of the equator inthe Eastern Hemisphere (+). Where data under these exact conditions were no available in the Western Hemisphere, data points form 8° August (□), 6° August (△), August (✱), and June (○) were inserted to allow a more complete delineation of the latitude structure. CIRA 1972 values are shown for comparison.

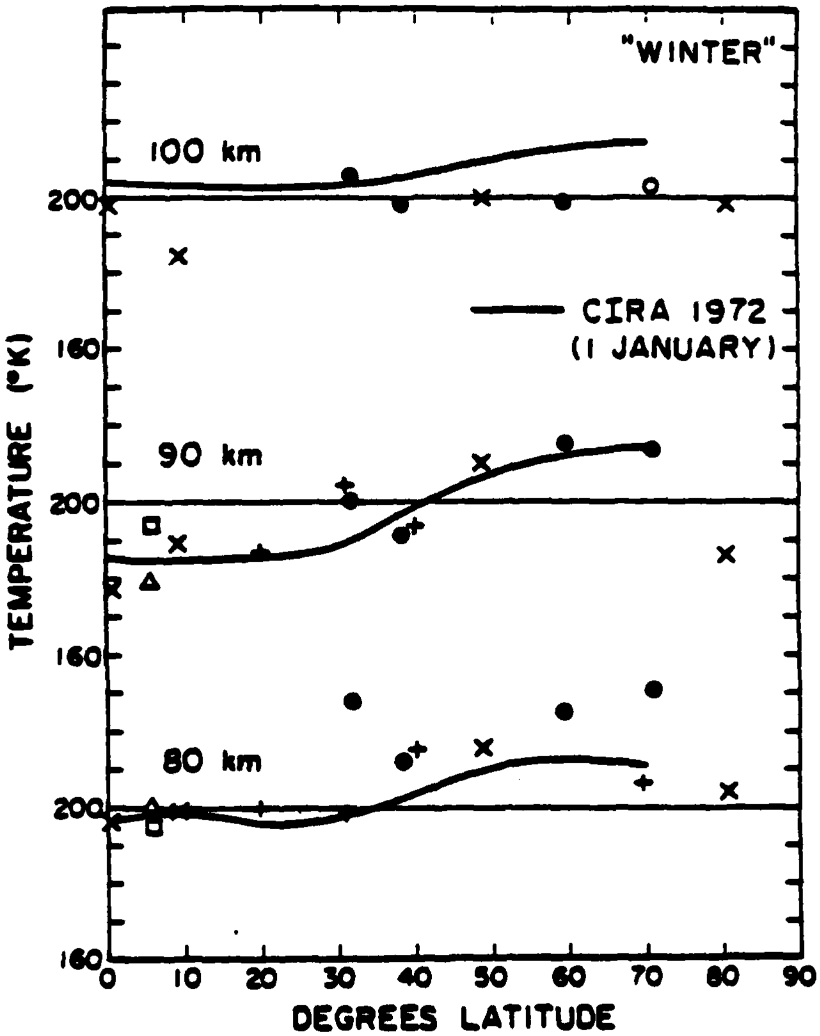

Figure 5. Temperature vs. latitude for measurements representative of January north of the equator in the Western (●) and Eastern (✕) Hemispheres. Where data under these exact conditions were not available in the Western Hemisphere, data points from 6°S February (□), 6° December (△), and February (○) were inserted toa llow a more complete delineation of the latitude structure. CIRA 1972 values are shown for comparison.

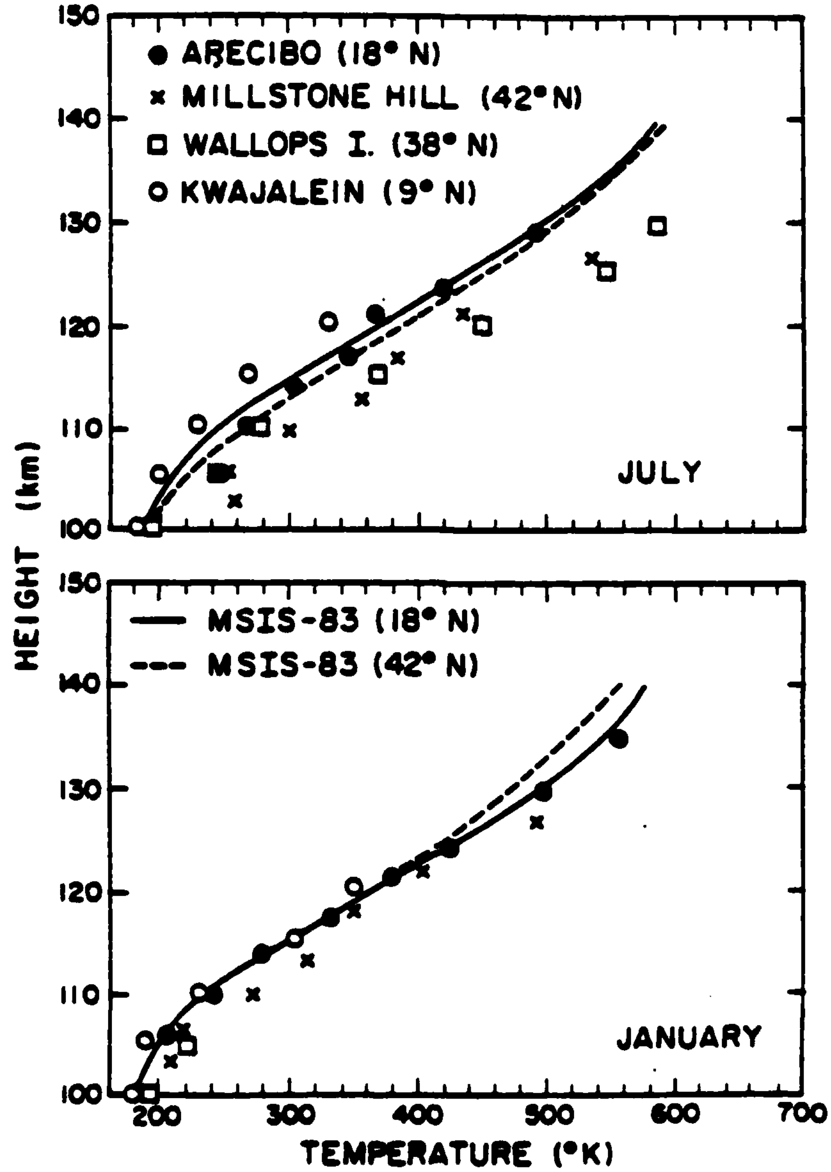

Figure 6. Vertical structures of temperature from 100Km to 130Km at various latitudes. MSIS-83 values are shown for comparison.

latitudes show the greatest degree of variability, so it was important that every possible piece of information be considered in development of the model.

3.3 Method of Analysis

The data set (consisting of monthly averages at the observing sites) is distributed unevenly in latitude, height, and by month. In order to construct monthly tables at 15^{o} latitude increment, it is necessary to fit the data in a least-squares sense using appropriate functions, and then to use these formulas to specify the data at 15o latitude increments. For a given month and altitude the best latitudinal fit with the least number of terms was found to be given by a function with the following form (θ = colatitude):

$$T(z) = T_0(z) + A_1\cos^2\theta + A_2\cos^3\theta + A_3\cos^4\theta$$

The fit was made to the data set from 70 to 120Km every 5Km for every month of the year. (A total of 11 X 12 = 121 fits). The polynomials were then used to generate temperature tables every 15^{o} latitude, every 5Km (70-120Km), for every month. These data do not, however, represent a smooth profile at any given latitude. The next step was to fit an analytic function to every 15^{o} latitude data set (for every month) between 70Km or so and 120Km such

that the temperature and temperature derivative match the corresponding values from the existing USAF Reference Atmosphere at some lower boundary. Specifically, the following procedure was found to work well: Only temperature data from 80 to 120Km in 5Km increments was included in the fit. Additional data points at 68, 72, 74, and 78Km were obtained from the old AFRA tables. A fourth-order polynomial in altitude was fit to all these data points. In all cases the fit was extremely close to the data points in the 70-90Km region, and formed a well-defined minimum (the mesopause) near 90Km. Tables were then generated every 2Km from the polynomial fit. A final adjustment at the lower boundary was made such that the 68Km point (generated from the polynomial) was replaced by the actual temperature value from the old AFRA tables, and the value at 70Km was replaced with the value obtained by linearly interpolating between the value at 68Km and the polynomial-generated value at 72Km. This ensured exact matching of temperature with the old AFRA at 68Km, very close (but approximate) matching with temperatures and gradients from the old AFRA between 70 and 80Km, merging into the newly-defined mesopause region (85-95Km) and lower-thermosphere (100-120Km) regions above.

It is important to note two points relating to the method analysis as adopted above. First, no attempt was made to impose or fit any functional dependence vs. month at a

given height or latitude. Second, since the temperature field at 120Km specified by the upper portion of the AFRA (which will probably be the MSIS-83 model) is dynamic and dependent on solar, geomagnetic, and other variations, a single match could not be performed at these levels to conform with the tabular nature of the model below 120Km.

3.4 Tables of Temperature, Pressure, and Density

Tables of monthly Temperature, Pressure, and Density extending from 70Km to 120Km in 2Km height increments at 0^{o}, 15^{o}N, 30^{o}N, 45^{o}N, 60^{o}N, and 75^{o}N are appended to this report. These tables are in exactly the same format as the existing Air Force Reference Atmosphere Tables (Cole and Kantor, 1978). The pressure tables were calculated using the barometric law and a reference pressure at 68Km equal to that given by the AFRA (Cole and Kantor, 1978). The latitude dependence of the acceleration due to gravity at sea level was taken from Cole and Kantor (1978), and the formula for the height dependence of g was taken from the 1966 U.S. Standard Atmosphere Supplements. The height dependence of the mean molecular weight above 90 Km was adopted from the MSIS model (Hedin et al, 1983) for equinox conditions, an F10.7 cm solar flux of 100 and Ap=15; the values for M from 80 to 120Km in steps of 10Km were as follows: 28.96, 28.90,

28.46, 27.42, 26.23 in a.m.u.. A linear interpolation was utilized at intermediate altitudes.

3.5 Variability

In addition to the marked seasonal variability depicted in the temperature, pressure, and density tables, within a given month or even a single day there exist significant variations about mean values due to gravity waves, tides, and perhaps other sources. Yet, while the Tables are based on temperature because it is the more globally available measured field, the variability characteristics of total mass density are of much greater Air Force operational concern. Therefore, density information from several typical stations are used here to quantitatively characterize the variability of density between 70 and 110Km. Specifically, the data employed originate from NASA MSRP data from Pt. Barrow (71°N), Ft. Churchill (59°N), Wallops I. (38°N) and the Natal (6°S) - Ascension (8°s) pair. (Smith <u>et al</u>, 1964; 1966,1967,1968,1969,1970,1971; Theon <u>et al</u>, 1972). The monthly and local time distributions from each of these sites is given in Figure 7. Of the 227 total soundings represented, 207 are grenade soundings (which yield temperature and horizontal winds as the primary variable, from which pressure and density are derived) and 20 pitot

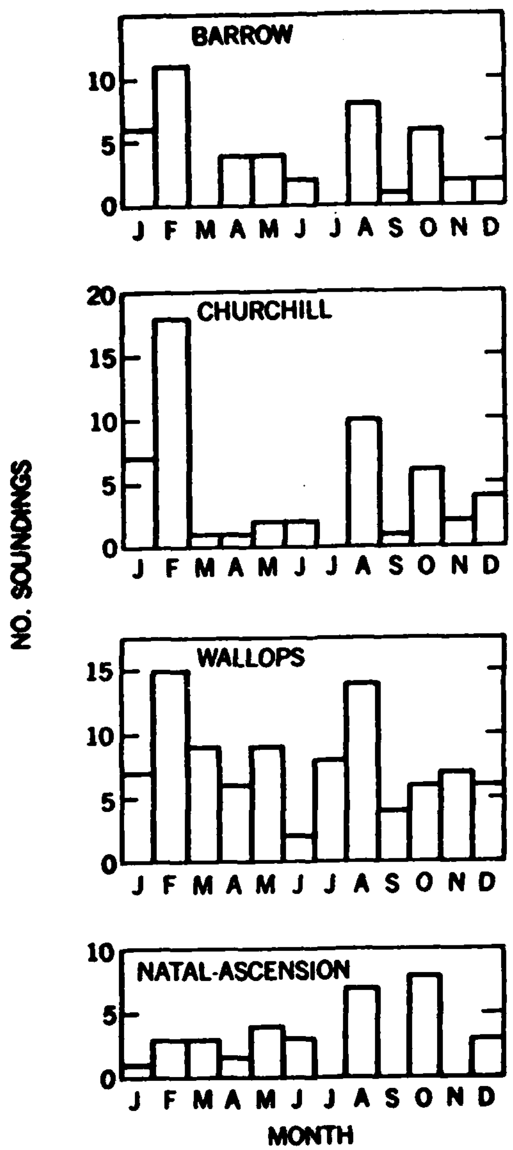

Figure 7(a)-The monthly distribution of the soundings for each site.

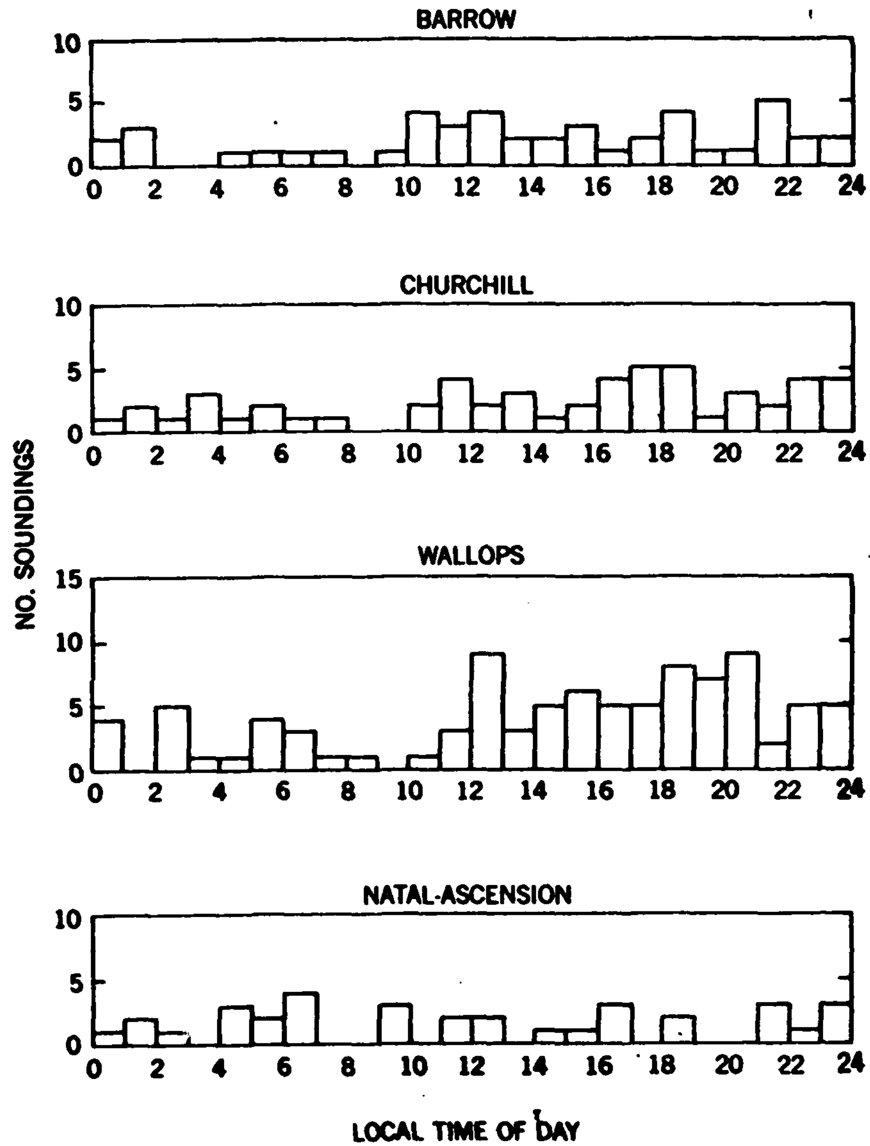

Figure 7(b)-The hourly distrubution of the soundings for each site.

probe soundings (which actually measure density). While there exist scattered falling-sphere density data which will enable important consistency checks on the current density tabulations, the NASA MSRP data represent the best statistical base to provide information on density variability as a function of season and latitude.

Percent Standard deviations of temperature and density from seasonal-mean values at Pt. Barrow, Ft. Churchill, and Wallops I. are given in Tables II-IV. Seasonal means are utilized to provide better statistics given the small number of soundings available. Values based on the combined stations of Natal ($6^{o}S$) and Ascension I ($8^{o}S$) are based on annual means in Table V due to the small seasonal variations present near the equator (Theon et al, 1972). Note that the standard deviations for temperature are generally smaller than for density, the latter values typically lying between 5-20% between 70 and 110Km.

Theoretical considerations must be invoked to explain the origin of the above variations. Note from Figure 7 that in toto the data are distributed over all parts of the day, with some bias towards the 1200-2000 hour local time period. However, within a given season the local time distribution is much more uneven, essentially precluding determination of tidal components; furthermore, by the same token, the

tabulated standard deviations do not fully account for tidal effects. Since tides represent global oscillations with fairly well-known excitation and propagation characteristics, useful theoretical estimates of this variability source can be obtained. The model of Forbes (1982a,b) has been utilized to produce such estimates. Figure 8 illustrates percent density departures from diurnal mean values for 80 and 100Km between 0 and 60^{O} latitude. An important feature to note is the small-amplitude tidal oscillation predicated polewardof about 54^{O} latitude. This implies that the density variations listed in the TABLES for Pt. Barrow (71^{O}N) and Ft. Churchill (59^{O}N) may be presumed to be predominantly a reflection of gravity wave effects. In fact, the height dependence of density standard deviations at Pt. Barrow is similar to that of radar echoes (and hence turbulent irregularities) observed with the MST Radar at Poker Flat (65^{O}N;

TABLE II

PERCENT STANDARD DEVIATIONS OF SEASONAL - MEAN TEMPERATURES AND DENSITIES AT PT. BARROW (71^{O}N)

	WINTER			SUMMER			SPRING/FALL		
ALT (Km)	TEMP ST.D.	DENSITY ST.D.	NO. OBSV.	TEMP ST.D.	DENSITY ST.D.	NO. OBSV.	TEMP ST.D.	DENSITY ST.D.	NO. OBSV.
70	6	20	18	3	6	10	9	24	16
74	7	19	18	2	7	9	5	26	16
78	9	17	18	2	8	9	6	29	16
82	10	13	17	2	7	8	9	29	16
86	9	12	17	4	8	8	13	26	13
90	9	10	15	7	10	7	14	21	11
94	5	7	6	24	14	2	2	11	3

TABLE III

PERCENT STANDARD DEVIATIONS OF SEASONAL - MEAN TEMPERATURES AND DENSITIES AT FT. CHURCHILL (59°N)

ALT (Km)	WINTER TEMP ST.D.	WINTER DENSITY ST.D.	WINTER NO. OBSV.	SUMMER TEMP ST.D.	SUMMER DENSITY ST.D.	SUMMER NO. OBSV.	SPRING/FALL TEMP ST.D.	SPRING/FALL DENSITY ST.D.	SPRING/FALL NO. OBSV.
70	5	17	29	2	6	12	3	19	13
74	7	17	29	3	6	12	3	20	13
78	8	16	28	4	7	12	5	21	13
82	9	14	27	6	9	12	6	19	13
86	6	14	26	6	9	12	6	8	12
90	11	13	19	10	15	7	12	15	9
94	5	10	11	.5	8	2	10	3	4
98	3	9	4	-	-	1			
102	7	13	4	-	-	1			
106	6	7	4	-	-	1			
110	16	16	4	-	-	1			
114	16	8	4	-	-	1			
118	15	11	4	-	-	1			

TABLE IV

PERCENT STANDARD DEVIATIONS OF SEASONAL - MEAN TEMPERATURE AND DENSITIES AT WALLOPS I. (38°N)

ALT (Km)	WINTER TEMP ST.D.	WINTER DENSITY ST.D.	WINTER NO. OBSV.	SUMMER TEMP ST.D.	SUMMER DENSITY ST.D.	SUMMER NO. OBSV.	SPRING/FALL TEMP ST.D.	SPRING/FALL DENSITY ST.D.	SPRING/FALL NO. OBSV.
70	4	9	28	4	9	23	4	13	38
74	7	10	25	5	8	23	6	13	38
78	7	8	21	7	9	20	7	14	36
82	7	11	16	6	9	18	8	12	32
86	6	10	10	8	14	16	8	10	31
90	11	18	6	8	13	13	14	14	19
94	-	-	1	6	8	5	3	6	3
98				9	1	4	3	.6	2
102				14	5	3	7	1	2
106				8	19	3	2	6	2
110				11	27	3	.1	10	2
114				6	25	2	4	11	2
118				5	27	2	8	11	2

TABLE V
PERCENT STANDARD DEVIATIONS OF ANNUAL - MEAN
TEMPERATURES AND DENSITIES AT NATAL - ASCENSION (6 TO 8°S)

ALT (Km)	TEMP ST.D.	DENSITY ST.D.	NO. OBSV.
70	4	6	32
74	5	9	31
78	6	7	30
82	5	10	30
86	8	10	30
90	11	12	29
94	14	13	12
98	22	16	3
102	23	.1	2
106	-	-	1

Balsey et al, 1983); that is, summer is characterized by the predominant occurence of echoes between 80 and 100Km, where as during

winter the echoes appear to originate predominantly below 80Km. The turbulence arises from convective instabilities associated with gravity waves whose level of breakdown is modulated by the seasonally-dependent mean winds of the troposphere and stratosphere.

The latitude dependence of gravity-wave related perturbations in the 70-100Km height region is not known. However, there is no reason to expect that gravity wave activity should increase significantly with decreasing latitude. The data in Figure 8, on the other hand, predict that tidal effects increase markedly as one gets closer to

the equator, suggesting that tides predominate equatorward of some intermediate latitude. The standard deviations of temperature and density in the Tables are in fact consistent with the temperature computations presented by Forbes(1982a,b) and the densities in Figure 8. At middle latitudes, say 30-55° latitude, it is not unreasonable to assume that tides and gravity waves contribute about equally to the observed variability of the region.

In the 100-120Km regime gravity waves most likely exist with amplitudes no greater than their convectively-limited values at lower levels, whereas tides experience exponential growth with height throughout the region. In addition, other sources of tides such as UV and EUV solar radiation absorption assume importance above 95-100Km. Estimated point density errors at 120Km as presented in Figure 9 commonly occur in the 15-30 % range. This order of magnitude is supported by the semidiurnal temperature perturbations obtained from an analysis of Millstone Hill (42°N) and Arecibo (18°N) temperatures performed by Dr. Forbes and presented in Figure 10. Figure 10 illustrates seasonal averages of the semidiurnal temperature oscillations as determined from 25 days of <u>simultaneous</u> measurements at Millstone Hill and Arecibo. These data represent a subset of the profiles utilized in constructing the monthly and diurnal-mean profiles discussed in Section 3.2. The

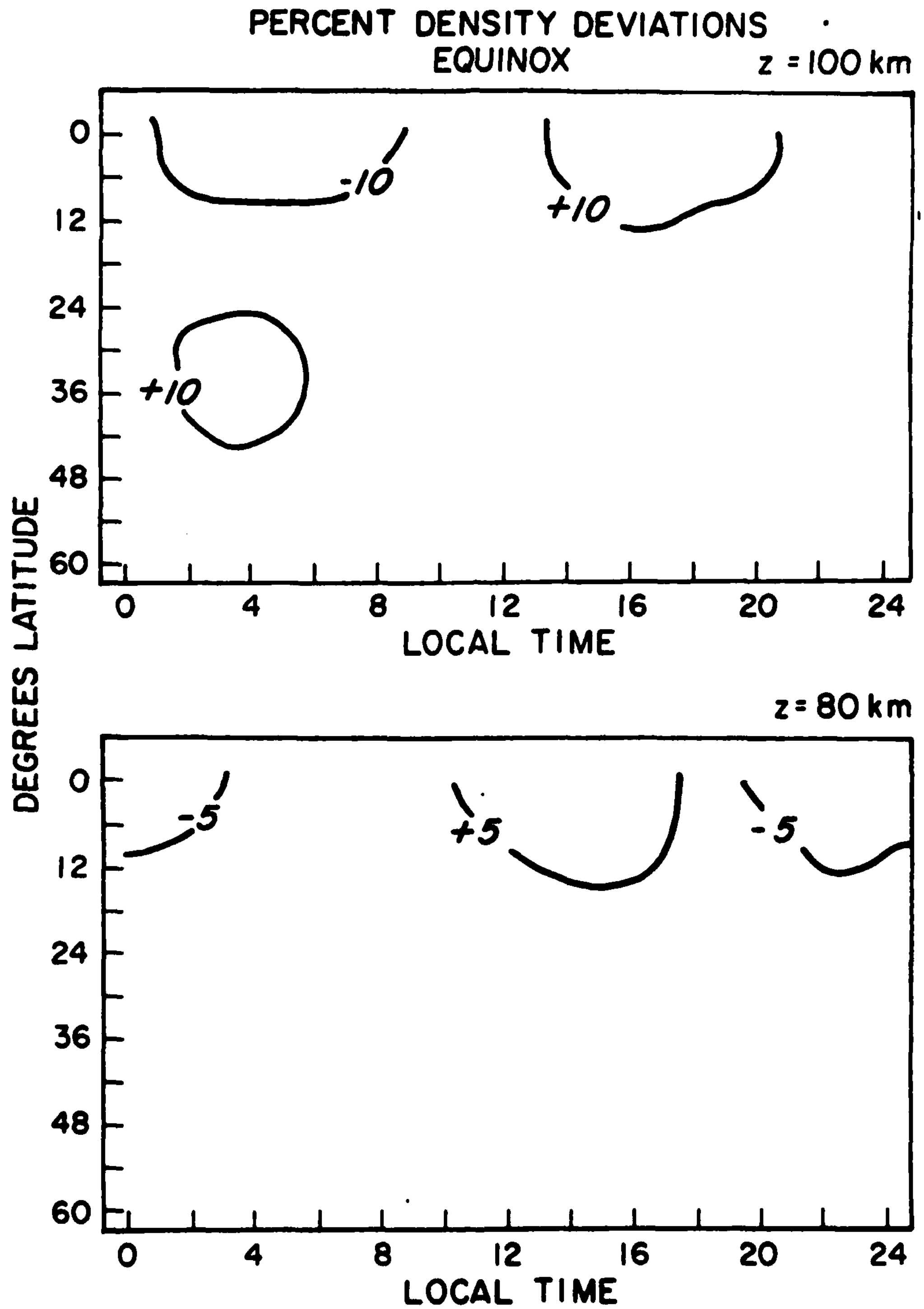

Figure 8. Estimated Percent Density derivations from the mean at equinox due to atmospheric tides.

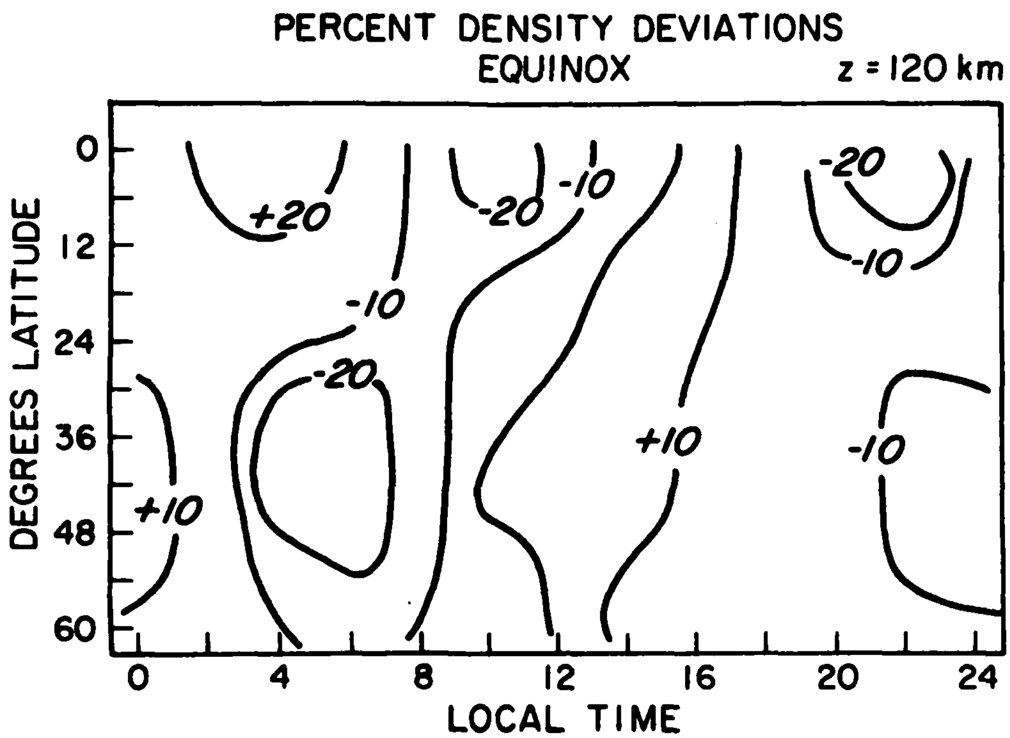

Figure 9 Estimated percent density derivations from mean at equinox due to atmospheric tides.

Millstone Hill amplitude profile is characterized by a peak near 110-115Km which varies in amplitude from 45K (summer, equinox) to 60K (winter). The Arecibo temperatures generally do not exhibit a well-defined peak. Both stations exhibit a downward phase progression with characteristic vertical scales of 30-45Km. Further, the Millstone Hill phases <u>lead</u> those at Arecibo by about 4 hours in summer, and <u>lag</u> the Arecibo phases by 4-6 hours during winter. These amplitude and phase characteristics suggest that the observations reflect the strong presence of (2,4) and (2,5) semidurnal tidal modes propagating upwards from below 100Km.

3.6 Discussion of Densities

Since total mass densities represent derived quantities in the appended tables, it is necessary to perform consistency checks for validation purposes, and to ascertain what new information these results provide. The average density profiles corresponding to the standard deviations listed in Tables III and IV are used to accomplish this. In addition, since MSIS-83 is a likely candidate for the AFRA at satellite altitudes, comparisons with this model are also made here to aid in the formulation of a means to merge the dynamic model above and the tables at lower heights (see also Section 3.4). These intercomparisons are performed at 90, 110, and 120Km in Figures 11, 12, and 13, respectively.

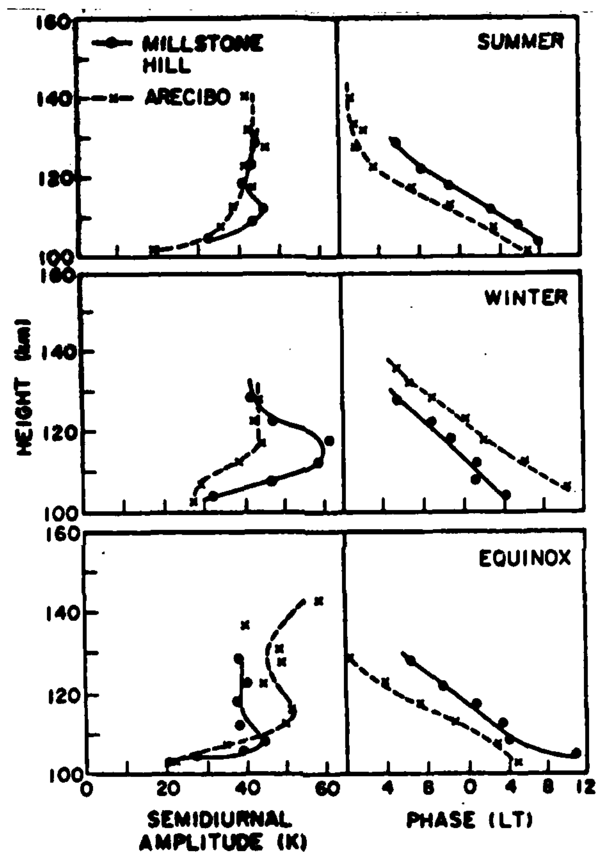

Figure 10 Seasonal averages of semidiurnal temperatures derived from 25 simultaneous daytime experiments at Arecibo and Millstone Hill.

The present model is seen to agree extremely well with the AFRA at 90Km (Figure 11). Both models indicate a predominantly annual variation, with a greater amplitude at $60^{o}N$ than $30^{o}N$. The only marked difference is that at $30^{o}N$ the AFRA predicts the density maximum to occur between February and April, whereas the present analysis indicates maximum densities during the April-June period; both models indicate a minimum in density to occur during the August-October period. At 60^{o} latitude the density maxima for both models occur during April-May with minima during December-January. The annual variation predicted by MSIS-83 is in good agreement at $60^{o}N$, but at $30^{o}N$ MSIS-83 contains little variation with month of the year. The densities at Pt. Barrow appear to contain a significant semiannual component, and about half the variability indicated by the other sources at $60^{o}N$. The Pt. Barrow data, on the other hand, appear to confirm the annual variation with amplitude and mean value about 20% less than the other models examined.

At 110Km (Figure 12), the current model indicates a more or less annual variation at high latitudes, but with maximum during December-April and minimum during June-July ... an approximately 180^{o} phase difference from the annual cycle at 90Km! The data at Ft. Churchill are in agreement with the phase and amplitude of this variation, but with a slightly

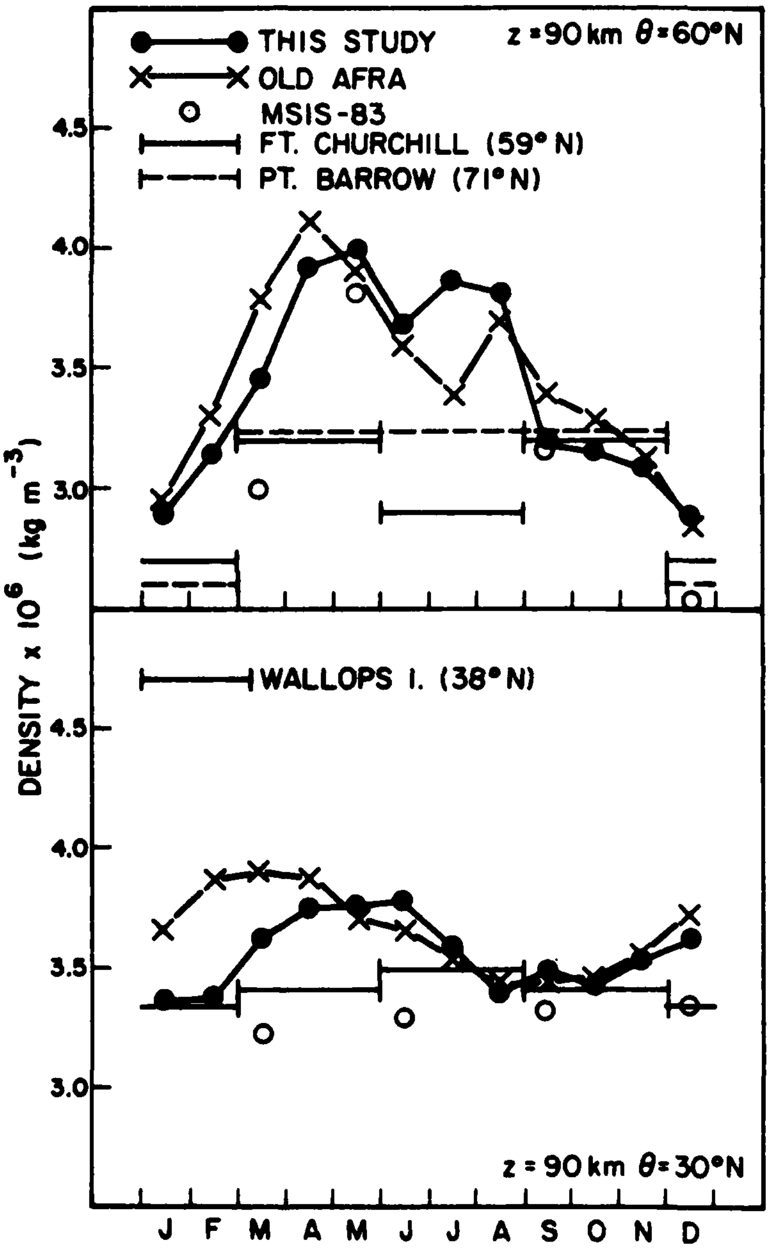

Figure 11. Data comparisons at 90 Km.

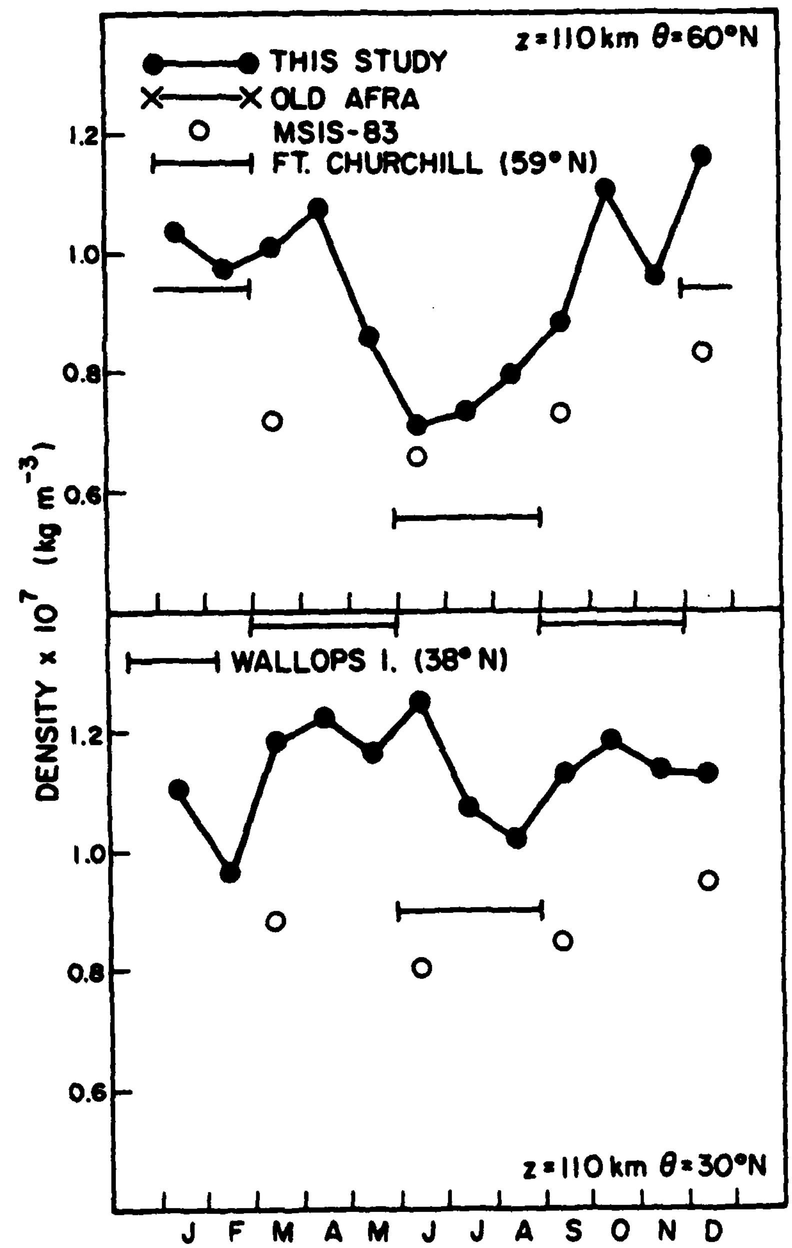

Figure 12. Data comparisons at 110 Km.

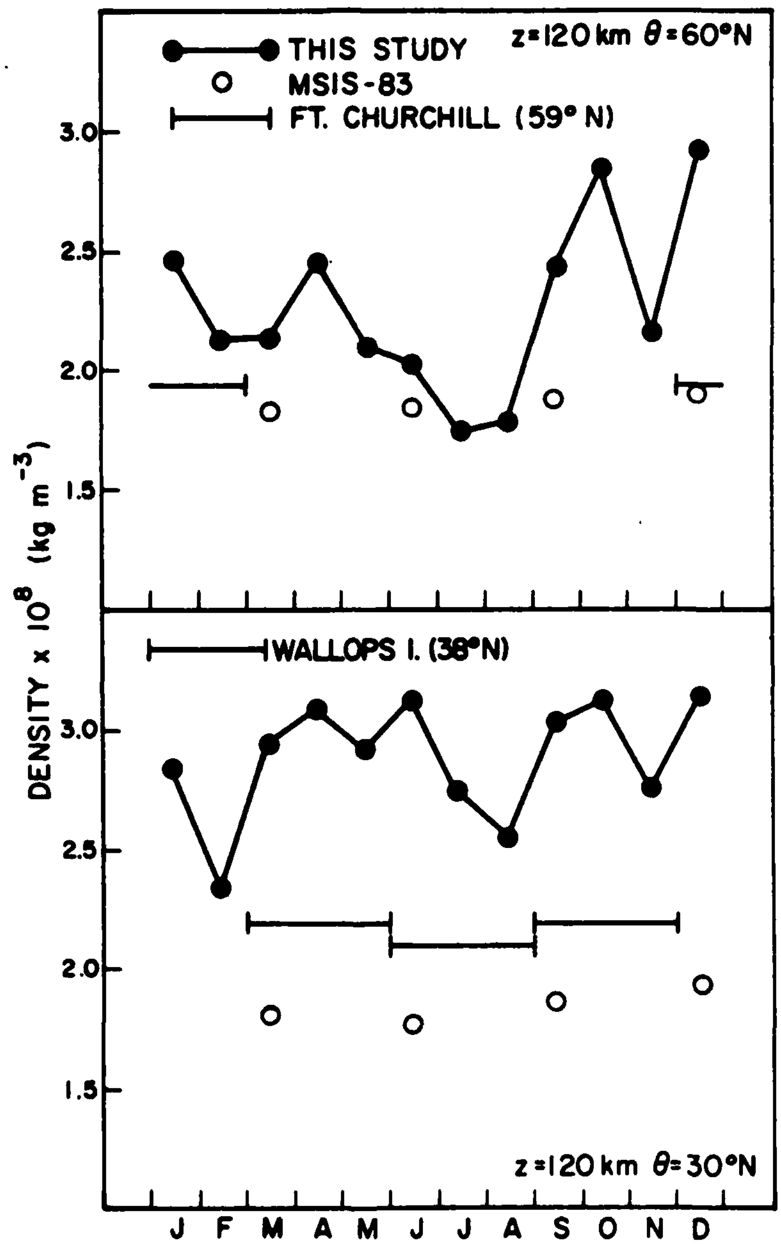

Figure 13. Data comparisons at 120 Km.

smaller mean value. The MSIS-83 model also agrees with the sense of this variation, except with a significantly smaller amplitude. The density variation at 30^{o} latitude now reflects a significant semiannual component. This result is not inconsistent with data at Wallops I., except that during winter months there does not exist sufficient data at this altitude to confirm the expected decrease in density. The MSIS-83 variation is still annual at 30^{o}N, with only a 10-12% amplitude and 30% smaller mean value.

At 120Km the semiannual variation at 30^{o} latitude is particularly predominant, while at 60^{o} latitude the distortion of the annual variation also indicates presence of a significant semiannual component as well. The Ft. Churchill data and MSIS-83 model yield similar overall magnitudes similar to the current results at 60^{o}N, but are approximately 30% less at 30^{o} latitude.

3.7 Merging with MSIS-83 above 120 Km

The above results suggest that MSIS-83 is in reasonably good agreement with available data at 90Km, but differs measurably at 110Km and 120Km, particularly at 30^{o} latitude where 20-30% underestimates are evident. Practical use of the new AFRA requires a functionally efficient algorithm for

merging the lower-altitude tables (<120Km) with the MSIS-83 model above. In addition, the MSIS-83 contains other geophysical variations such as those connected with solar and geomagnetic activity which are not relevant at lower altitudes. It is recommended that, at least initially, the merging of these two model segments be accomplished as follows:

(1) Store tabular data below 110Km

(2) Use MSIS-83 computer algorithm down to 130Km

(3) Between 110Km and 130Km determine density and pressure by linearly interpolating the natural logarithms of these fields, and determine temperature by direct linear interpolation.

The above method will naturally damp out solar - geomagnetic variations from 130Km to 110Km. However, internal consistency between pressure, density, and temperature will not necessarily be maintained between 110Km and 130Km. This should not be cause for concern for operational utilization of the model. In addition, the first derivatives of these fields will not match at 110Km and 130Km. After initial experimentation with the merging method described above, more sophisticated methods of smoothing, or modification of the exact altitudes of matching, may warrant examination.

Unless specific solar, geomagnetic, and geophysical inputs to MSIS-83 are given, it is not possible to provide a usable or useful set of tables covering the 80-200km regime, unless these would be constructed solely for illustrative purposes; this is because the matching conditions would have to be changed for each set of solar geophysical conditions specified. Rather, the model must by given in computer algorithm form for those who would ultimately make operational use of the model. For these reasons, the tables given here only extend to 120Km, and a recommended method of merging has been provided for implementation in the working version of the new AFRA.

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MONTHLY TEMPERATURE (K) AT THE EQUATOR

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	222.27	220.28	215.76	211.65	209.97	209.80	210.56	209.34	210.01	210.51	212.32	214.76
72.000	214.34	212.29	207.51	203.53	203.18	204.83	207.36	204.58	204.67	204.25	206.26	207.21
74.000	209.10	206.74	203.56	199.87	200.27	201.37	203.42	201.41	201.33	201.36	203.45	203.11
76.000	203.99	201.29	200.06	196.91	197.97	198.45	199.86	198.92	198.53	199.11	201.09	199.43
78.000	199.04	195.99	196.93	194.52	196.10	195.97	196.59	197.02	196.13	197.33	199.02	196.12
80.000	194.31	190.93	194.07	192.62	194.49	193.84	193.59	195.62	194.00	195.88	197.10	193.14
82.000	189.88	186.18	191.46	191.12	193.04	192.02	190.83	194.66	192.06	194.67	195.24	190.47
84.000	185.84	181.84	189.08	189.99	191.67	190.48	188.33	194.10	190.28	193.64	193.40	188.13
86.000	182.29	178.04	186.95	189.20	190.36	189.23	186.10	193.92	188.64	192.76	191.58	186.15
88.000	179.33	174.88	185.14	188.75	189.11	188.30	184.22	194.12	187.19	192.06	189.80	184.57
90.000	177.11	172.51	183.74	188.67	187.98	187.74	182.76	194.73	185.99	191.57	188.14	183.48
92.000	175.74	171.07	182.86	189.03	187.05	187.64	181.83	195.80	185.14	191.37	186.74	182.96
94.000	175.40	170.71	182.66	189.89	186.46	188.10	181.56	197.38	184.78	191.60	185.75	183.15
96.000	176.24	171.62	183.33	191.36	186.37	189.27	182.11	199.56	185.11	192.39	185.37	184.17
98.000	178.44	173.96	185.09	193.58	187.80	191.31	183.65	202.46	186.33	193.95	185.86	186.19
100.000	182.20	177.94	188.20	196.70	188.60	194.40	186.40	206.20	188.70	196.50	187.50	189.40
102.000	187.72	183.76	192.94	200.90	191.46	198.77	190.58	210.94	192.51	200.30	190.62	194.01
104.000	195.22	191.63	199.63	206.39	195.92	204.65	196.45	216.84	198.10	205.65	195.59	200.24
106.000	204.93	201.79	208.62	213.40	202.35	212.33	204.29	224.11	205.81	212.89	202.83	208.35
108.000	217.10	214.47	220.29	222.19	211.16	222.09	214.41	232.95	216.07	222.38	212.79	218.61
110.000	231.98	229.93	235.08	233.04	222.81	234.26	227.12	243.60	229.31	234.53	225.98	231.33
112.000	249.84	248.44	253.41	246.26	237.78	249.19	242.80	256.33	246.00	249.79	242.92	246.81
114.000	270.98	270.26	275.79	262.18	256.62	267.26	261.82	271.41	266.66	268.62	264.21	265.40
116.000	295.68	295.69	302.72	281.16	279.91	288.87	284.57	289.14	291.85	291.55	298.46	287.46
118.000	324.27	325.03	334.75	303.59	308.25	314.45	311.50	309.84	322.14	319.13	322.34	313.39
120.000	357.05	358.59	372.47	329.87	342.30	344.46	343.05	333.86	358.17	351.93	360.56	343.58

MONTHLY TEMPERATURE (K) AT 15 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	220.74	218.93	215.66	212.95	211.43	209.74	210.97	209.74	210.51	210.65	214.32	216.67
72.000	214.85	213.07	208.95	206.39	206.49	206.81	209.02	206.83	207.35	207.21	209.20	210.13
74.000	209.74	207.60	204.82	202.44	203.09	203.33	204.76	203.10	203.57	203.73	206.02	206.43
76.000	204.76	202.22	201.12	199.11	200.24	200.38	200.85	199.91	200.27	200.82	203.24	203.16
78.000	200.00	197.02	197.77	196.33	197.81	197.88	197.27	197.24	197.30	198.39	200.76	200:26
80.000	195.53	192.10	194.76	194.04	195.72	195.75	194.03	195.07	194.85	196.38	198.51	197.68
82.000	191.45	187.58	192.09	192.23	193.90	193.98	191.16	193.39	192.67	194.76	196.43	195.41
84.000	187.86	183.56	189.78	190.87	192.34	192.53	188.70	192.21	190.83	193.50	194.51	193.46
86.000	184.87	180.18	187.87	189.99	191.03	191.42	186.70	191.55	189.37	192.63	192.80	191.86
88.000	182.59	177.56	186.44	189.61	190.03	190.70	185.24	191.45	188.35	192.17	191.33	190.65
90.000	181.15	175.84	185.57	189.78	189.39	190.42	184.40	191.98	187.83	192.19	190.21	189.91
92.000	180.67	175.16	185.38	190.58	189.22	190.66	184.30	193.19	187.92	192.78	189.55	189.75
94.000	181.29	175.67	186.02	192.10	189.66	191.55	185.04	195.17	188.75	194.03	189.54	190.28
96.000	183.15	177.53	187.64	194.45	190.86	193.20	186.77	198.02	190.47	196.10	190.35	191.65
98.000	186.40	180.90	190.43	197.77	193.03	195.79	189.63	201.85	193.25	199.12	192.21	194.03
100.000	191.21	185.96	194.60	202.20	196.40	199.50	193.80	206.80	197.30	203.30	195.40	197.60
102.000	197.73	192.88	200.39	207.92	201.22	204.54	199.46	213.00	202.84	208.83	200.21	202.59
104.000	206.14	201.84	208.05	215.12	207.79	211.14	206.81	220.61	210.12	215.95	206.96	209.23
106.000	216.61	213.03	217.87	224.01	216.44	219.56	216.06	229.81	219.42	224.91	216.03	217.78
108.000	229.33	226.66	230.15	234.83	227.51	230.09	227.44	240.78	231.03	235.99	227.81	228.53
110.000	244.50	242.93	245.22	247.82	241.40	243.03	241.21	253.73	245.27	249.51	242.75	241.79
112.000	262.31	262.04	263.43	263.27	258.52	258.73	257.63	268.87	262.50	265.78	261.29	257.88
114.000	282.97	284.23	285.15	281.47	279.33	277.53	276.98	286.44	283.09	285.16	283.96	277.17
116.000	306.69	309.70	310.79	302.72	304.32	299.82	299.54	306.67	307.43	308.04	311.28	300.02
118.000	333.70	338.70	340.77	327.37	333.99	326.00	325.64	329.85	335.94	334.82	343.82	326.84
120.000	364.23	371.45	375.53	355.76	368.89	356.52	355.60	356.23	369.07	365.92	382.19	358.65

MONTHLY TEMPERATURE (K) AT 30 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	221.23	220.36	221.75	219.40	217.88	215.90	214 03	213.08	216.10	217.55	220.09	221.75
72.000	217.83	216.24	214.67	212.59	212.32	211.05	211 23	210.67	212.70	213.14	215.40	215.95
74.000	213.24	211.25	210.51	208.00	207.49	206.65	20[illegible] 12	205.87	207.86	208.60	211.56	213.07
76.000	208.76	206.31	206.63	203.82	203.05	202.76	201.35	201.38	203.33	204.46	207.96	210.55
78.000	204.52	201.54	203.07	200.09	199.05	199.39	196.99	197.27	199.23	200.81	204.60	208.35
80.000	200.65	197.10	199.90	196.87	195.53	196.55	193.15	193.63	195.68	197.71	201.52	206.42
82.000	197.28	193.11	197.16	194.21	192.56	194.26	189.94	190.53	192.79	195.26	198.77	204.75
84.000	194.53	189.72	194.95	192.17	190.21	192.58	187.44	188.09	190.66	193.53	196.42	203.36
86.000	192.53	187.08	193.33	190.85	188.58	191.55	185.77	186.40	189.41	192.60	194.56	202.27
88.000	191.39	185.31	192.41	190.32	187.77	191.23	185.01	185.58	189.13	192.57	193.30	201.55
90.000	191.24	184.58	192.28	190.68	187.88	191.70	185.29	185.74	189.93	193.52	192.76	201.28
92.000	192.19	185.01	193.05	192.04	189.04	193.05	186.69	187.03	191.91	195.54	193.10	201.57
94.000	194.34	186.76	194.85	194.51	191.39	195.38	189.32	189.56	195.16	198.72	194.49	202.55
96.000	197.82	189.97	197.79	198.22	195.08	198.80	193.29	193.40	199.79	203.16	197.11	204.37
98.000	202.72	194.78	202.03	203.30	200.26	203.43	198.72	198.95	205.87	208.96	201.17	207.22
100.000	209.15	201.33	207.70	209.90	207.10	209.40	205.69	206.12	213.52	216.22	206.90	211.30
102.000	217.22	209.78	214.96	218.17	215.79	216.86	214.33	215.16	222.81	225.03	214.55	216.84
104.000	227.01	220.26	223.98	228.28	226.53	225.97	224.74	226.23	233.83	235.50	224.38	224.08
106.000	238.64	232.94	234.93	240.39	239.53	236.90	237.03	239.52	246.67	247.73	236.68	233.32
108.000	252.18	247.94	248.00	254.70	254.99	249.83	251.32	255.22	261.41	261.34	251.76	244.84
110.000	267.75	265.43	263.37	271.39	273.16	264.95	267.72	273.53	278.13	277.92	269.94	258.97
112.000	285.41	285.55	281.26	290.66	294.28	282.47	286.34	294.64	296.90	296.10	291.57	276.06
114.000	305.26	308.44	301.87	312.72	318.60	302.60	307.29	318.77	317.81	316.49	317.02	296.48
116.000	327.39	334.27	325.41	337.80	346.39	325.57	330.78	346.13	340.93	339.19	346.66	320.63
118.000	351.87	363.17	352.13	366.12	377.93	351.63	356.68	376.95	366.33	364.34	380.91	348.94
120.000	378.78	395.30	382.26	397.93	413.51	381.01	385.34	411.47	394.08	392.04	420.19	381.83

MONTHLY TEMPERATURE (K) AT 45 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	226.89	225.42	224.71	223.88	223.10	229.14	214.75	214.17	217.91	222.15	227.70	228.35
72.000	224.14	221.25	220.22	218.67	216.54	213.86	210.09	210.35	216.02	218.71	224.35	224.77
74.000	220.47	217.45	216.56	213.57	210.00	206.55	204.01	205.13	210.24	213.93	220.54	222.16
76.000	216.77	213.58	213.00	208.68	203.71	199.68	198.34	200.18	204.64	209.38	216.65	219.71
78.000	213.16	209.74	209.59	204.09	197.84	193.48	193.18	195.54	199.44	205.19	212.75	217.41
80.000	209.78	206.03	206.38	199.91	192.54	188.15	188.64	191.25	194.88	201.52	208.96	215.28
82.000	206.74	202.56	203.44	196.26	187.99	183.87	184.84	187.41	191.15	198.50	205.39	213.35
84.000	204.18	199.45	200.84	193.24	184.34	180.81	181.87	184.11	188.44	196.27	202.15	211.68
86.000	202.21	196.82	198.68	190.98	181.74	179.09	179.86	181.49	186.91	194.95	199.39	210.33
88.000	200.97	194.82	197.07	189.58	180.34	178.85	178.91	179.68	186.72	194.65	197.27	209.41
90.000	200.59	193.60	196.11	189.17	180.27	180.18	179.15	178.85	188.00	195.49	195.96	209.00
92.000	201.19	193.32	195.94	189.86	181.69	183.15	180.69	179.20	190.86	197.56	195.65	209.23
94.000	202.91	194.16	196.70	191.80	184.71	187.84	183.67	180.93	195.40	200.96	196.53	210.25
96.000	205.87	196.29	198.53	195.09	189.47	194.27	188.19	184.26	201.70	205.78	198.82	212.22
98.000	210.22	199.91	201.60	199.88	196.10	202.46	194.39	189.46	209.81	212.10	202.76	215.30
100.000	216.07	205.23	206.10	206.30	204.70	212.40	202.40	196.80	219.80	220.00	208.59	219.70
102.000	223.57	212.46	212.21	214.48	215.40	224.08	212.34	206.57	231.68	229.54	216.57	225.63
104.000	232.85	221.82	220.12	224.57	228.31	237.44	224.35	219.08	245.45	240.77	226.97	233.31
106.000	244.04	233.56	230.06	236.69	243.52	252.42	238.56	234.67	261.12	253.76	240.09	243.00
108.000	257.28	247.91	242.25	251.00	261.15	268.93	255.12	253.71	278.66	268.55	256.22	254.96
110.000	272.70	265.14	256.93	267.65	281.28	286.87	274.15	276.56	298.02	285.17	275.70	269.47
112.000	290.45	285.52	274.35	286.78	304.01	306.11	295.81	303.64	319.14	303.66	298.85	286.83
114.000	310.66	309.32	294.77	308.54	329.43	326.49	320.24	335.36	341.94	324.03	326.03	307.37
116.000	333.47	336.83	318.47	333.10	357.61	347.86	347.57	372.16	366.33	346.31	357.59	331.42
118.000	359.01	368.36	345.73	360.60	388.64	370.01	377.97	414.52	392.18	370.51	393.93	359.33
120.000	387.44	404.21	376.86	391.20	422.58	392.74	411.57	462.91	419.38	396.63	435.42	391.48

MONTHLY TEMPERATURE (K) AT 60 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	236.03	230.63	227.16	227.18	224.59	220.28	215.25	214.04	217.80	225.32	234.63	237.95
72.000	233.40	228.25	224.91	222.23	217.49	212.74	206.55	206.74	215.68	222.36	231.61	234.25
74.000	229.89	224.98	221.09	216.51	209.22	201.30	198.53	201.04	209.08	218.07	228.24	231.12
76.000	226.07	221.45	217.16	210.83	201.12	190.20	191.03	195.77	202.57	213.82	224.45	227.81
78.000	222.07	217.71	213.15	205.33	193.44	179.91	184.16	190.90	196.42	209.75	220.34	224.43
80.000	218.02	213.82	209.11	200.15	186.38	170.85	178.03	186.41	190.87	206.00	216.02	221.07
82.000	214.06	209.87	205.11	195.42	180.18	163.38	172.75	182.31	186.17	202.70	211.63	217.86
84.000	210.34	205.96	201.23	191.27	175.04	157.79	168.45	178.68	182.54	199.99	207.32	214.92
86.000	207.00	202.24	197.60	187.84	171.13	154.34	165.24	175.59	180.16	198.01	203.25	212.39
88.000	204.21	198.84	194.33	185.24	168.63	153.22	163.26	173.20	179.22	196.86	199.62	210.39
90.000	202.12	195.95	191.58	183.62	167.69	154.55	162.63	171.66	179.87	196.69	196.63	209.07
92.000	200.93	193.76	189.50	183.08	168.46	158.41	163.49	171.18	182.26	197.61	194.50	208.59
94.000	200.78	192.49	188.28	183.77	171.06	164.82	165.98	172.00	186.49	199.74	193.48	209.08
96.000	201.89	192.37	188.13	185.79	175.60	173.75	170.25	174.41	192.68	203.19	193.82	210.73
98.000	204.42	193.68	189.25	189.27	182.19	185.09	176.45	178.73	200.89	208.08	195.80	213.69
100.000	208.59	196.70	191.90	194.32	190.90	198.70	184.73	185.30	211.20	214.51	199.72	218.15
102.000	214.59	201.73	196.33	201.06	201.80	214.37	195.25	194.52	223.64	222.60	205.89	224.28
104.000	222.63	209.10	202.81	209.61	214.95	231.84	208.17	206.82	238.23	232.44	214.63	232.27
106.000	232.93	219.16	211.64	220.08	230.38	250.77	223.66	222.66	254.98	244.14	226.31	242.32
108.000	245.71	232.28	223.14	232.58	248.13	270.81	241.89	242.54	273.87	257.79	241.28	254.63
110.000	261.20	248.86	237.63	247.21	268.19	291.50	263.05	267.00	294.87	273.50	259.93	269.41
112.000	279.63	269.32	255.47	264.08	290.57	312.36	287.30	296.62	317.91	291.34	282.67	286.87
114.000	301.25	294.08	277.03	283.31	315.24	332.85	314.83	332.01	342.93	311.42	309.91	307.23
116.000	326.30	323.61	302.69	304.98	342.18	352.34	345.84	373.82	369.82	333.81	342.10	330.72
118.000	355.04	358.40	332.86	329.21	371.32	370.20	380.52	422.74	398.48	358.60	379.69	357.58
120.000	387.72	398.94	367.98	356.10	402.62	385.69	419.07	479.49	428.77	385.87	423.15	388.04

MONTHLY TEMPERATURE (K) AT 75 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D
70.000	241.54	235.04	230.11	227.28	224.97	221.99	216.64	214.91	218.30	225.79	236.56	242.02
72.000	242.98	235.56	229.25	224.08	215.86	210.43	204.04	203.30	214.81	224.43	236.25	241.17
74.000	238.10	231.19	223.83	217.28	205.76	195.57	192.84	196.10	206.79	220.11	232.97	237.18
76.000	232.59	226.31	218.05	210.40	195.81	180.96	182.19	189.52	198.78	215.67	229.06	232.70
78.000	226.68	221.05	212.07	203.65	186.32	167.25	172.33	183.51	191.13	211.28	224.63	227.94
80.000	220.61	215.55	206.05	197.21	177.61	154.99	163.50	178.08	184.15	207.10	219.84	223.09
82.000	214.64	209.97	200.16	191.29	169.94	144.69	155.88	173.26	178.14	203.31	214.86	218.34
84.000	208.98	204.50	194.55	186.06	163.57	136.74	149.69	169.13	173.37	200.06	209.86	213.89
86.000	203.86	199.32	189.41	181.70	158.73	131.48	145.10	165.78	170.07	197.50	205.05	209.93
88.000	199.50	194.63	184.92	178.35	155.61	129.17	142.28	163.33	168.44	195.79	200.64	206.65
90.000	196.11	190.65	181.26	176.19	154.38	129.96	141.38	161.96	168.67	195.07	196.86	204.23
92.000	193.90	187.60	178.62	175.33	155.19	133.95	142.55	161.86	170.92	195.48	193.97	202.85
94.000	193.07	185.72	177.21	175.93	158.16	141.16	145.90	163.26	175.29	197.16	192.23	202.70
96.000	193.82	185.26	177.22	178.10	163.40	151.52	151.54	166.42	181.89	200.24	191.91	203.96
98.000	196.33	186.50	178.87	181.96	170.96	164.87	159.58	171.62	190.78	204.84	193.32	206.80
100.000	200.80	189.70	182.36	187.60	180.90	181.00	170.10	179.20	202.00	211.10	196.78	211.39
102.000	207.40	195.17	187.92	195.12	193.23	199.60	183.16	189.51	215.56	219.13	202.61	217.91
104.000	216.29	203.19	195.77	204.61	207.94	220.28	198.83	202.93	231.44	229.04	211.17	226.52
106.000	227.66	214.11	206.15	216.14	225.01	242.57	217.13	219.89	249.60	240.94	222.81	237.40
108.000	241.66	228.23	219.29	229.77	244.36	265.94	238.11	240.84	269.95	254.94	237.93	250.69
110.000	258.45	245.91	235.43	245.57	265.93	289.76	261.77	266.27	292.40	271.14	256.91	266.58
112.000	278.17	267.50	254.82	263.56	289.60	313.33	288.10	296.69	316.81	289.63	280.18	285.21
114.000	300.97	293.38	277.71	283.80	315.22	335.87	317.11	332.65	343.02	310.51	308.16	306.74
116.000	326.99	323.92	304.37	306.31	342.65	356.50	348.75	374.73	370.84	333.87	341.31	331.33
118.000	356.36	359.52	335.05	331.10	371.69	374.30	382.98	423.55	400.05	359.78	380.08	359.13
120.000	389.21	400.59	370.02	358.18	402.13	388.24	419.75	479.74	430.42	388.32	424.96	390.29

MONTHLY PRESSURE (MB) AT THE EQUATOR

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	5.7421	5.7475	5.8890	5.8252	5.6501	5.4685	5.3591	5.4208	5.5390	5.6235	5.6476	5.6691	-2
72.000	4.2293	4.2214	4.2946	4.2218	4.0890	3.9583	3.8964	3.9273	4.0149	4.0753	4.1049	4.1309	
74.000	3.0873	3.0713	3.1050	3.0336	2.9383	2.8512	2.8174	2.8284	2.8915	2.9338	2.9649	2.9851	
76.000	2.2371	2.2166	2.2331	2.1692	2.1037	2.0438	2.0250	2.0282	2.0727	2.1043	2.1338	2.1448	
78.000	1.6078	1.5856	1.5968	1.5437	1.5006	1.4585	1.4478	1.4492	1.4794	1.5041	1.5299	1.5319	
80.000	1.1468	1.1246	1.1367	1.0952	1.0679	1.0370	1.0296	1.0330	1.0522	1.0727	1.0939	1.0888	
82.000	8.1138	7.9050	8.0516	7.7451	7.5777	7.3486	7.2881	7.3485	7.4579	7.6326	7.7954	7.6902	-3
84.000	5.6999	5.5122	5.6823	5.4686	5.3681	5.1945	5.1352	5.2234	5.2712	5.4240	5.5413	5.4234	
86.000	3.9751	3.8125	3.9928	3.8548	3.7932	3.6631	3.6041	3.7112	3.7145	3.8478	3.9262	3.8047	
88.000	2.7562	2.6196	2.7975	2.7152	2.6762	2.5793	2.5208	2.6381	2.6115	2.7278	2.7748	2.6621	
90.000	1.9009	1.7893	1.9537	1.9117	1.8837	1.8148	1.7572	1.8769	1.8316	1.9317	1.9548	1.8577	
92.000	1.3073	1.2182	1.3629	1.3478	1.3248	1.2759	1.2230	1.3383	1.2832	1.3683	1.3745	1.2956	
94.000	8.9846	8.2865	9.5051	9.5218	9.3119	8.9882	8.5144	9.5758	8.9897	9.7024	9.6521	9.0418	-4
96.000	6.1857	5.6472	6.6415	6.7489	6.5497	6.3476	5.9337	6.8797	6.3843	6.8941	6.7775	6.3258	
98.000	4.2769	3.8668	4.6555	4.8038	4.6132	4.5013	4.1581	4.9690	4.4328	4.9135	4.7641	4.4427	
100.000	2.9788	2.6689	3.2829	3.4396	3.2682	3.2097	2.9166	3.6112	3.1305	3.5184	3.3596	3.1395	
102.000	2.0964	1.8634	2.3343	2.4888	2.3162	2.3068	2.0669	2.6452	2.2266	2.5360	2.3826	2.2371	
104.000	1.4969	1.3215	1.6808	1.8078	1.6604	1.6755	1.4808	1.9568	1.6003	1.8459	1.7062	1.6138	
106.000	1.0861	.9536	1.2272	1.3316	1.2029	1.2318	1.0753	1.4629	1.1648	1.3584	1.2362	1.1782	
108.000	8.0312	7.0215	9.1190	9.9412	8.8487	9.1066	7.9302	11.0710	8.6118	10.1380	9.0986	8.7433	-5
110.000	6.0556	5.2786	6.9019	7.5250	6.6085	6.9594	5.9524	8.4870	6.4781	7.6817	6.8146	6.5962	
112.000	4.6643	4.0579	5.3352	5.7898	5.0232	5.3649	4.5534	6.5095	4.9712	5.9249	5.2109	5.0709	
114.000	3.6679	3.1880	4.2109	4.5261	3.8994	4.2109	3.5542	5.2074	3.8945	4.6548	4.0708	3.9716	
116.000	2.9466	2.5603	3.3988	3.6024	3.0941	3.3685	2.8313	4.1734	3.1180	3.7292	3.2544	3.1734	
118.000	2.4144	2.0984	2.7991	2.9166	2.5078	2.7453	2.3821	3.3967	2.5580	3.0463	2.6680	2.5837	
120.000	2.0175	1.7544	2.3543	2.4044	2.0776	2.2797	1.9089	2.8085	2.1297	2.5383	2.2233	2.1447	

MONTHLY PRESSURE (MB) AT 15 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	5.6637	5.6613	5.7331	5.7347	5.7596	5.5795	5.3688	5.4189	5.4413	5.5480	5.5929	5.6243	-2
72.000	4.1696	4.1576	4.1861	4.1707	4.1852	4.0517	3.9103	3.9354	3.9554	4.0325	4.0809	4.1130	
74.000	3.0463	3.0287	3.0329	3.0100	3.0225	2.9270	2.8340	2.8433	2.8600	2.9157	2.9602	2.9864	
76.000	2.2093	2.1884	2.1849	2.1685	2.1726	2.1049	2.0404	2.0429	2.0563	2.0976	2.1381	2.1577	
78.000	1.5981	1.5680	1.5648	1.5428	1.5550	1.5070	1.4608	1.4613	1.4715	1.5029	1.5378	1.5511	
80.000	1.1360	1.1140	1.1152	1.0974	1.1091	1.0748	1.0397	1.0410	1.0482	1.0730	1.1022	1.1105	
82.000	8.0572	7.8490	7.9079	7.7780	7.8846	7.6424	7.3637	7.3936	7.4389	7.6387	7.8720	7.9181	-3
84.000	5.6777	5.4884	5.5862	5.5005	5.5913	5.4203	5.1906	5.2393	5.2616	5.4261	5.6058	5.6287	
86.000	3.9770	3.8108	3.9310	3.8822	3.9557	3.8371	3.6460	3.7083	3.7121	3.8486	3.9798	3.9887	
88.000	2.7730	2.6310	2.7593	2.7385	2.7940	2.7125	2.5527	2.6235	2.6135	2.7273	2.8190	2.8212	
90.000	1.9267	1.8087	1.9328	1.9315	1.9709	1.9166	1.7845	1.8575	1.8383	1.9326	1.9923	1.9920	
92.000	1.3371	1.2411	1.3536	1.3647	1.3903	1.3548	1.2467	1.3179	1.2931	1.3710	1.4069	1.4066	
94.000	9.2925	8.5265	9.4944	9.6732	9.8211	9.6009	8.7296	9.3901	9.1166	9.7550	9.9399	9.9458	-4
96.000	6.4806	5.8782	6.6812	6.8876	6.9548	6.8240	6.1305	6.7231	6.4474	6.9664	7.0353	7.0527	
98.000	4.5476	4.0799	4.7259	4.9332	4.9458	4.8751	4.3310	4.8472	4.5848	5.0032	4.9967	5.0229	
100.000	3.2186	2.8582	3.3674	3.5601	3.5375	3.5040	3.0808	3.5217	3.2820	3.6171	3.5684	3.5998	
102.000	2.3044	2.0282	2.4232	2.5933	2.5514	2.5407	2.2145	2.5847	2.3723	2.6394	2.5693	2.6016	
104.000	1.6741	1.4625	1.7668	1.9117	1.8610	1.8625	1.6115	1.9192	1.7354	1.9477	1.8714	1.9019	
106.000	1.2357	1.0733	1.3070	1.4272	1.3752	1.3827	1.1899	1.4436	1.2873	1.4560	1.3815	1.4080	
108.000	9.2848	8.0313	9.8343	10.8120	10.3200	10.4130	8.9248	11.0100	9.6992	11.0410	10.3660	10.5840	-5
110.000	7.1053	6.1311	7.5314	8.3141	7.8747	7.9668	6.8113	8.5223	7.4336	8.5049	7.9171	8.0823	
112.000	5.5429	4.7783	5.8808	6.5001	6.1218	6.1988	5.2913	6.6980	5.8008	6.6613	6.1675	6.2833	
114.000	4.4065	3.8002	4.6809	5.1661	4.8509	4.9095	4.1882	5.3480	4.6125	5.3086	4.9021	4.9727	
116.000	3.5699	3.0832	3.8006	4.1773	3.9210	3.9589	3.3760	4.3375	3.7373	4.3856	3.9789	4.0105	
118.000	2.9441	2.5487	3.1442	3.4340	3.2313	3.2505	2.7717	3.5736	3.0850	3.5537	3.2949	3.2932	
120.000	2.4703	2.1450	2.6501	2.8706	2.7143	2.7162	2.3151	2.9891	2.5926	2.9835	2.7833	2.7541	

MONTHLY PRESSURE (MB) AT 30 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	4.9737	5.1267	5.4402	5.8127	5.9100	5.8930	5.7415	5.4218	5.4197	5.2258	5.1666	5.1209	-2
72.000	3.6700	3.7770	4.0046	4.2660	4.3331	4.3113	4.1968	3.9588	3.9712	3.8335	3.8023	3.7731	
74.000	2.6941	2.7648	2.9258	3.1062	3.1534	3.1325	3.0491	2.8744	2.8921	2.7940	2.7819	2.7643	
76.000	1.9642	2.0090	2.1257	2.2474	2.2790	2.2618	2.1979	2.0716	2.0910	2.0232	2.0247	2.0183	
78.000	1.4230	1.4492	1.5354	1.6157	1.6362	1.6239	1.5733	1.4833	1.5019	1.4563	1.4658	1.4682	
80.000	1.0243	1.0376	1.1035	1.1554	1.1675	1.1601	1.1181	1.0549	1.0719	1.0426	1.0561	1.0652	
82.000	7.3324	7.3786	7.8916	8.2206	8.2862	8.2535	7.9014	7.4618	7.6108	7.4315	7.5744	7.7063	-3
84.000	5.2226	5.2138	5.6236	5.8283	5.8553	5.8534	5.5547	5.2517	5.3806	5.2794	5.4113	5.5653	
86.000	3.7059	3.6652	3.9940	4.1201	4.1235	4.1425	3.8919	3.6843	3.7940	3.7429	3.8528	4.0110	
88.000	2.6229	2.5665	2.8321	2.9094	2.8986	2.9292	2.7208	2.5786	2.6720	2.6522	2.7369	2.8885	
90.000	1.8550	1.7936	2.0064	2.0543	2.0367	2.0722	1.9023	1.8047	1.8836	1.8815	1.9415	2.0784	
92.000	1.3136	1.2537	1.4235	1.4540	1.4337	1.4692	1.3327	1.2652	1.3318	1.3390	1.3779	1.4968	
94.000	9.3402	8.7944	10.1320	10.3370	10.1380	10.4640	9.3870	8.9167	9.4749	9.5850	9.8065	10.8010	-4
96.000	6.6789	6.2028	7.2499	7.3967	7.2143	7.4960	6.6558	6.3245	6.7909	6.9101	7.0097	7.8203	
98.000	4.8161	4.4128	5.2237	5.3370	5.1793	5.4125	4.7656	4.5302	4.9172	5.0286	5.0447	5.6880	
100.000	3.5065	3.1726	3.7979	3.8904	3.7580	3.9440	3.4493	3.2803	3.6004	3.6980	3.6624	4.1634	
102.000	2.5849	2.3122	2.7916	2.8708	2.7629	2.9070	2.5311	2.4094	2.6727	2.7541	2.6898	3.0724	
104.000	1.9324	1.7120	2.0801	2.1497	2.0630	2.1714	1.8856	1.7976	2.0139	2.0804	2.0039	2.2924	
106.000	1.4667	1.2895	1.5720	1.6342	1.5660	1.6453	1.4279	1.3645	1.5417	1.5949	1.5165	1.7309	
108.000	1.1309	.9889	1.2072	1.2630	1.2098	1.2659	1.0995	1.0541	1.1992	1.2416	1.1678	1.3257	
110.000	8.8612	7.7237	9.4185	9.9228	9.5141	9.8942	8.6119	8.2934	9.4806	9.8160	9.1560	10.3040	-5
112.000	7.0563	6.1447	7.4745	7.9310	7.6196	7.8602	6.8596	6.6427	7.6148	7.8818	7.3154	8.1433	
114.000	5.7092	4.9771	6.0296	6.4443	6.2115	6.3462	5.5563	5.4172	6.2127	6.4255	5.9546	6.5427	
116.000	4.6908	4.1018	4.9465	5.3240	5.1525	5.2870	4.5723	4.4927	5.1442	5.3161	4.9373	5.3496	
118.000	3.9115	3.4362	4.1216	4.4668	4.3445	4.3390	3.8210	3.7879	4.3207	4.4606	4.1660	4.4476	
120.000	3.3072	2.9233	3.4884	3.8050	3.7210	3.6704	3.2388	3.2417	3.6772	3.7932	3.5746	3.7610	

MONTHLY PRESSURE (MB) AT 45 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	4.5721	4.7993	5.2195	5.7125	6.2649	6.4645	6.0777	5.6205	5.3059	4.8800	4.6702	4.4967	-2
72.000	3.4001	3.5580	3.8647	4.2235	4.6227	4.7735	4.4386	4.1037	3.9022	3.6047	3.4751	3.3476	
74.000	2.5180	2.6241	2.8463	3.1007	3.3798	3.4725	3.2150	2.9757	2.8531	2.6474	2.5740	2.4827	
76.000	1.8555	1.9253	2.0862	2.2602	2.4476	2.5008	2.3069	2.1404	2.0676	1.9312	1.8967	1.8355	
78.000	1.3605	1.4048	1.5213	1.6360	1.7556	1.7803	1.6408	1.5280	1.4865	1.3999	1.3982	1.3526	
80.000	9.9262	10.1950	11.0420	11.7610	12.4760	12.5570	11.5700	10.8230	10.5970	10.0850	10.1340	9.9400	-3
82.000	7.2091	7.3577	7.9770	8.4017	8.7896	8.7722	8.0987	7.6134	7.5051	7.2281	7.3475	7.2842	
84.000	5.2143	5.2842	5.7398	5.9697	6.1474	6.0916	5.6327	5.3204	5.2837	5.1588	5.3004	5.3262	
86.000	3.7592	3.7777	4.1146	4.2230	4.2745	4.2074	3.9000	3.6983	3.7079	3.6723	3.8062	3.8866	
88.000	2.7039	2.6911	2.9415	2.9786	2.9615	2.9037	2.6927	2.5598	2.5976	2.6110	2.7230	2.8324	
90.000	1.9429	1.9121	2.0987	2.0980	2.0493	2.0052	1.8587	1.7679	1.8230	1.8581	1.9429	2.0625	
92.000	1.3971	1.3577	1.4970	1.4790	1.4210	1.3929	1.2859	1.2209	1.2846	1.3262	1.3852	1.5026	
94.000	1.0078	.9657	1.0695	1.0465	.9910	.9753	.8951	.8463	.9129	.9523	.9893	1.0969	
96.000	7.3024	6.8928	7.6655	7.4464	6.9697	6.9124	6.2812	5.8997	6.5502	6.8888	7.0903	8.0327	-4
98.000	5.3281	4.9497	5.5227	5.3418	4.9593	4.9638	4.4580	4.1532	4.7630	5.0332	5.1144	5.9103	
100.000	3.9196	3.5836	4.0068	3.8706	3.5776	3.6223	3.2051	2.9591	3.5113	3.7178	3.7206	4.3753	
102.000	2.9149	2.6235	2.9348	2.8402	2.6238	2.6867	2.3415	2.1425	2.6320	2.7830	2.7388	3.2659	
104.000	2.1954	1.9476	2.1759	2.1153	1.9600	2.0307	1.7408	1.5805	2.0064	2.1135	2.0457	2.4638	
106.000	1.6765	1.4682	1.6350	1.6005	1.4922	1.5611	1.3185	1.1903	1.5568	1.6297	1.5531	1.8807	
108.000	1.2993	1.1259	1.2475	1.2316	1.1584	1.2224	1.0177	.9160	1.2284	1.2760	1.2004	1.4551	
110.000	1.0224	.8789	.9672	.9640	.9165	.9723	.8006	.7208	.9858	1.0145	.9453	1.1420	
112.000	8.1720	6.9892	7.6275	7.6785	7.3877	7.8637	6.4156	5.7978	8.0342	8.1886	7.5887	9.1032	-5
114.000	6.6343	5.6606	6.1191	6.2205	6.0612	6.4481	5.2348	4.7646	6.6486	6.7073	6.2086	7.3713	
116.000	5.4685	4.6687	4.9952	5.1237	5.0569	5.3644	4.3443	3.9950	5.5763	5.5706	5.1746	6.0664	
118.000	4.5745	3.9173	4.1462	4.2871	4.2847	4.5142	3.6638	3.4137	4.7390	4.6887	4.3891	5.0716	
120.000	3.8807	3.3417	3.4984	3.6413	3.6830	3.8453	3.1359	2.9673	4.0731	3.9953	3.7848	4.3065	

MONTHLY PRESSURE (MB) AT 60 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	3.5748	4.0276	4.6428	5.7022	6.6188	7.3875	7.2306	6.5462	5.1010	4.3757	3.8185	3.4966	-2
72.000	2.6884	3.0092	3.4540	4.2342	4.8910	5.4275	5.2641	4.7613	3.7491	3.2458	2.8659	2.6334	
74.000	2.0144	2.2404	2.5593	3.1217	3.5751	3.9297	3.7834	3.4295	2.7371	2.3959	2.1427	1.9756	
76.000	1.5026	1.6607	1.8864	2.2831	2.5808	2.7921	2.6843	2.4487	1.9776	1.7581	1.5950	1.4765	
78.000	1.1153	1.2252	1.3831	1.6563	1.8395	1.9461	1.8799	1.7332	1.4152	1.2826	1.1812	1.0989	
80.000	8.2349	8.9919	10.0820	11.9150	12.9410	13.2940	13.0020	12.1670	10.0220	9.3022	8.6992	8.1437	-3
82.000	6.0475	6.5634	7.3062	8.5041	8.9924	8.9171	8.8871	8.4724	7.0362	6.7117	6.3680	6.0090	
84.000	4.4177	4.7637	5.2630	6.0245	6.1780	5.8851	6.0128	5.8572	4.9001	4.8201	4.6331	4.4167	
86.000	3.2110	3.4380	3.7695	4.2401	4.2048	3.8404	4.0337	4.0217	3.3947	3.4496	3.3498	3.2340	
88.000	2.3235	2.4676	2.6845	2.9682	2.8419	2.4904	2.6902	2.7466	2.3436	2.4628	2.4079	2.3612	
90.000	1.6754	1.7623	1.9025	2.0701	1.9139	1.6166	1.7889	1.8680	1.6187	1.7570	1.7217	1.7199	
92.000	1.2054	1.2538	1.3431	1.4416	1.2895	1.0574	1.1908	1.2686	1.1217	1.2549	1.2265	1.2519	
94.000	8.6746	8.9048	9.4667	10.0548	8.7354	7.0234	7.9714	8.6293	7.8389	8.9982	8.7234	9.1227	-4
96.000	6.2521	6.3217	6.6689	7.0378	5.9783	4.7552	5.3847	5.8972	5.5342	6.4865	6.2062	6.6643	
98.000	4.5253	4.4984	4.7089	4.9577	4.1353	3.2973	3.6859	4.0646	3.9643	4.7133	4.4298	4.8982	
100.000	3.2949	3.2157	3.3387	3.5230	2.9099	2.3426	2.5640	2.8355	2.8834	3.4565	3.1804	3.6186	
102.000	2.4211	2.3180	2.3863	2.5332	2.0875	1.7085	1.8188	2.0110	2.1367	2.5651	2.3857	2.6888	
104.000	1.8001	1.6909	1.7247	1.8478	1.5295	1.2776	1.3198	1.4558	1.6135	1.9294	1.6942	2.0246	
106.000	1.3568	1.2516	1.2640	1.3692	1.1453	.9785	.9787	1.0782	1.2430	1.4726	1.2648	1.5434	
108.000	1.0385	.9425	.9416	1.0321	.8765	.7655	.7434	.8188	.9756	1.1412	.9619	1.1931	
110.000	8.0000	7.2346	7.1441	7.9173	6.8509	6.1076	5.7777	6.3763	7.8026	8.9831	7.4617	9.3590	-5
112.000	6.3963	5.6683	5.5284	6.1840	5.4641	4.9543	4.5922	5.0946	6.3475	7.1827	5.9109	7.4579	
114.000	5.1532	4.5355	4.3671	4.9168	4.4418	4.0802	3.7277	4.1710	5.2510	5.8329	4.7815	6.0372	
116.000	4.2246	3.7061	3.5216	3.9782	3.6746	3.4016	3.0866	3.4951	4.4077	4.8083	3.9490	4.9668	
118.000	3.5225	3.0982	2.8979	3.2726	3.0894	2.8672	2.6026	2.9909	3.7528	4.0213	3.3258	4.1480	
120.000	2.9849	2.6267	2.4312	2.7352	2.6356	2.4370	2.2316	2.6096	3.2340	3.4092	2.8533	3.5176	

MONTHLY PRESSURE (MB) AT 75 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	2.9689	3.2344	4.1544	5.3474	6.9657	8.2296	8.2852	7.0421	5.2218	3.7798	3.2534	3.0417	-2
72.000	2.2537	2.4349	3.1058	3.9766	5.1411	6.0408	6.0237	5.1071	3.8358	2.8084	2.4517	2.3062	
74.000	1.7068	1.8282	2.3118	2.9367	3.7424	4.3441	4.2981	3.6513	2.7928	2.0785	1.8435	1.7435	
76.000	1.2842	1.3644	1.7075	2.1474	2.6816	3.0437	3.0080	2.5812	2.0074	1.5288	1.3799	1.3114	
78.000	9.6011	10.1210	12.5160	15.5490	18.8960	20.7260	20.6230	18.0300	14.2480	11.1780	10.2780	9.8113	-3
80.000	7.1197	7.4512	9.0899	11.1380	13.0860	13.6810	13.8490	12.4610	9.9759	8.1206	7.6089	7.2946	
82.000	5.2398	5.4454	6.5444	7.8992	8.9094	8.7572	9.1133	8.5180	6.9007	5.8657	5.5972	5.3910	
84.000	3.8233	3.9461	4.6665	5.5455	5.9703	5.4465	5.8878	5.7701	4.7194	4.2133	4.0881	3.9589	
86.000	2.7690	2.8373	3.2984	3.8598	3.9472	3.3113	3.7446	3.8744	3.2014	3.0134	2.9653	2.8909	
88.000	1.9899	2.0231	2.3106	2.6659	2.5833	1.9847	2.3553	2.5856	2.1593	2.1476	2.1354	2.0998	
90.000	1.4219	1.4327	1.6070	1.8319	1.6814	1.1869	1.4728	1.7171	1.4551	1.5282	1.5282	1.5191	
92.000	1.0112	1.0082	1.1108	1.2552	1.0945	.7168	.9223	1.1395	.9837	1.0874	1.0878	1.0961	
94.000	7.1854	7.0748	7.6596	8.6131	7.1731	4.4285	5.8272	7.5826	6.7124	7.7644	7.7231	7.9104	-4
96.000	5.1069	4.9556	5.2768	5.9314	4.7566	2.8185	3.7376	5.0813	4.6365	5.5693	5.4766	5.7173	
98.000	3.6465	3.4798	3.6480	4.1170	3.2093	1.8593	2.4483	3.4424	3.2582	4.0261	3.8931	4.1515	
100.000	2.6200	2.4547	2.5366	2.8864	2.2099	1.2716	1.6442	2.3685	2.3322	2.9367	2.7809	3.0335	
102.000	1.9033	1.7488	1.7831	2.0524	1.5588	.9023	1.1358	1.6615	1.7062	2.1684	2.0056	2.2383	
104.000	1.4010	1.2625	1.2714	1.4835	1.1279	.6622	.8086	1.1938	1.2761	1.6233	1.4656	1.6716	
106.000	1.0480	.9269	.9225	1.0920	.8374	.5013	.5929	.8796	.9762	1.2340	1.0888	1.2661	
108.000	7.9749	6.9365	6.8249	8.1926	6.3728	3.8959	4.4746	6.6602	7.6269	9.5301	8.2434	9.7377	-5
110.000	6.1834	5.3028	5.1583	6.2681	4.9655	3.0990	3.4678	5.1784	6.0829	7.4826	6.3726	7.6135	
112.000	4.8838	4.1436	3.9842	4.8889	3.9543	2.5127	2.7551	4.1362	4.9416	5.9712	5.0341	6.0534	
114.000	3.9320	3.3119	3.1469	3.8866	3.2127	2.0714	2.2384	3.3858	4.0859	4.8440	4.0656	4.8961	
116.000	3.2226	2.7049	2.5390	3.1457	2.6577	1.7300	1.8559	2.8383	3.4301	3.9909	3.3541	4.0261	
118.000	2.6885	2.2562	2.0917	2.5901	2.2346	1.4608	1.5666	2.4289	2.9216	3.3384	2.8243	3.3647	
120.000	2.2789	1.9183	1.7562	2.1665	1.9061	1.2433	1.3440	2.1197	2.5188	2.8317	2.4233	2.8549	

MONTHLY DENSITY (KG/M^3) AT THE EQUATOR

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	8.9996	9.0895	9.5085	9.5880	9.3743	9.0669	8.8666	9.0209	9.1881	9.3062	9.2664	9.1961	-5
72.000	6.8739	6.9272	7.2097	7.2262	7.0109	6.7321	6.5460	6.6877	6.8338	6.9509	6.9331	6.9450	
74.000	5.1435	5.1754	5.3138	5.2874	5.1112	4.9326	4.8249	4.8922	5.0032	5.0757	5.0768	5.1199	
76.000	3.8204	3.8362	3.8885	3.8378	3.7019	3.5877	3.5298	3.5520	3.6371	3.6817	3.6965	3.7466	
78.000	2.8141	2.8183	2.8247	2.7647	2.6658	2.5927	2.5656	2.5625	2.6278	2.6553	2.6780	2.7211	
80.000	2.0561	2.0519	2.0405	1.9808	1.9127	1.8637	1.8528	1.8395	1.8895	1.9078	1.9334	1.9639	
82.000	1.4881	1.4786	1.4645	1.4112	1.3670	1.3327	1.3300	1.3146	1.3522	1.3654	1.3984	1.4076	
84.000	1.0677	1.0552	1.0461	1.0020	.9749	.9493	.9492	.9368	.9643	.9751	.9974	1.0035	
86.000	7.5880	7.4515	7.4318	7.0882	6.9338	6.7361	6.7390	6.6594	6.8520	6.9462	7.1313	7.1123	-6
88.000	5.3461	5.2106	5.2560	5.0038	4.[illegible]225	4.7648	4.7584	4.7272	4.8527	4.9404	5.0853	5.0171	
90.000	3.7319	3.6066	3.6972	3.5232	3.4844	3.3597	3.3432	3.3515	3.4243	3.5061	3.6127	3.5205	
92.000	2.5801	2.4698	2.5849	2.4728	2.4564	2.3583	2.3327	2.3786	2.4038	2.4798	2.5527	2.4560	
94.000	1.7720	1.6792	1.8001	1.7345	1.7276	1.6530	1.6223	1.6783	1.6830	1.7518	1.7976	1.7078	
96.000	1.2110	1.1354	1.2500	1.2169	1.2126	1.1572	1.1243	1.1895	1.1751	1.2364	1.2615	1.1851	
98.000	8.2487	7.6498	8.6563	8.5404	8.4901	8.0975	7.7771	8.4466	8.1874	8.7187	8.8216	8.2119	-7
100.000	5.6120	5.1486	5.9877	6.0025	5.9337	5.6675	5.3711	6.0117	5.6947	6.1463	6.1505	5.6899	
102.000	3.8120	3.4614	4.1297	4.2151	4.1293	3.9613	3.7019	4.2805	3.9479	4.3218	4.2665	3.9359	
104.000	2.6026	2.3406	2.8577	2.9729	2.8766	2.7788	2.5584	3.0629	2.7419	3.0466	2.9608	2.7342	
106.000	1.7887	1.5949	1.9853	2.1059	2.0063	1.9578	1.7764	2.2030	1.9100	2.1535	2.0570	1.9084	
108.000	1.2414	1.0986	1.3891	1.5014	1.4049	1.3881	1.2411	1.5948	1.3373	1.5298	1.4348	1.3421	
110.000	8.7093	7.6595	9.7956	10.7730	9.8837	9.9118	8.7442	11.6240	9.4255	10.9280	10.0610	9.5136	-8
112.000	6.1906	5.4162	6.9813	7.7951	7.0051	7.1390	6.2187	8.5373	6.7009	7.8653	7.1131	6.8129	
114.000	4.4608	3.8875	5.0318	5.6892	5.0076	5.1924	4.4737	6.3230	4.8130	5.7097	5.0775	4.9317	
116.000	3.2638	2.8358	3.6763	4.1962	3.6203	3.8191	3.2585	4.7272	3.4990	4.1891	3.6695	3.6155	
118.000	2.4233	2.1012	2.7214	3.1268	2.6478	2.8415	2.4053	3.5679	2.5763	3.1067	2.6857	2.6833	
120.000	1.8274	1.5823	2.0443	2.3574	1.9630	2.1405	1.7997	2.7207	1.9231	2.3327	1.9942	2.0188	

MONTHLY DENSITY (KG/M^3) AT 15 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	8.9383	9.0084	9.2611	9.3815	9.4899	9.2672	8.8654	9.0006	9.0046	9.1751	9.0910	9.0429	-5
72.000	6.7609	6.7976	6.9791	7.0398	7.0608	6.8251	6.5172	6.6286	6.6454	6.7796	6.7957	6.8189	
74.000	5.0598	5.0824	5.1586	5.1798	5.1846	5.0163	4.8217	4.8771	4.8942	4.9856	5.0055	5.0398	
76.000	3.7588	3.7700	3.7845	3.7801	3.7797	3.6594	3.5391	3.5601	3.5770	3.6388	3.6648	3.6999	
78.000	2.7697	2.7724	2.7564	2.7376	2.7385	2.6531	2.5798	2.5809	2.5971	2.6391	2.6685	2.6983	
80.000	2.0240	2.0202	1.9947	1.9702	1.9740	1.9127	1.8666	1.8590	1.8740	1.9034	1.9343	1.9571	
82.000	1.4656	1.4571	1.4336	1.4090	1.4160	1.3720	1.3414	1.3314	1.3445	1.3658	1.3956	1.4111	
84.000	1.0521	1.0408	1.0246	1.0032	1.0119	.9800	.9576	.9489	.9598	.9762	1.0032	1.0128	
86.000	7.4859	7.3596	7.2811	7.1103	7.2056	6.9753	6.7955	6.7366	6.8211	6.9522	7.1829	7.2342	-6
88.000	5.2826	5.1543	5.1481	5.0239	5.1144	4.9477	4.7935	4.7665	4.8267	4.9366	5.1250	5.1474	
90.000	3.6982	3.5766	3.6215	3.5389	3.6186	3.4998	3.3649	3.3644	3.4030	3.4965	3.6420	3.6472	
92.000	2.5668	2.4575	2.5324	2.4836	2.5482	2.4646	2.3460	2.3659	2.3865	2.4665	2.5742	2.5710	
94.000	1.7732	1.6791	1.7656	1.7419	1.7913	1.7339	1.6320	1.6644	1.6709	1.7392	1.8141	1.8082	
96.000	1.2209	1.1425	1.2286	1.2222	1.2573	1.2187	1.1326	1.1715	1.1680	1.2257	1.2753	1.2698	
98.000	8.3964	7.7617	8.5408	8.5846	8.8179	8.5693	7.8602	8.2645	8.1649	8.6474	8.9467	8.9091	-7
100.000	5.7780	5.2760	5.9399	6.0438	6.1827	6.0290	5.4567	5.8456	5.7100	6.1074	6.2687	6.2534	
102.000	3.9781	3.5894	4.1277	4.2574	4.3281	4.2400	3.7897	4.1420	3.9921	4.3141	4.3803	4.3833	
104.000	2.7564	2.4593	2.8824	3.0163	3.0399	2.9940	2.6447	2.9527	2.8033	3.0613	3.0691	3.0853	
106.000	1.9253	1.7003	2.0246	2.1502	2.1443	2.1254	1.8586	2.1200	1.9800	2.1848	2.1582	2.1820	
108.000	1.3586	1.1890	1.4339	1.5450	1.5221	1.5187	1.3168	1.5345	1.4088	1.5700	1.5270	1.5541	
110.000	9.6958	8.4205	10.2470	11.1930	10.8840	10.9370	9.4214	11.2060	10.1120	11.3730	10.8810	11.1530	-8
112.000	7.0070	6.0467	7.4025	8.1871	7.8522	7.9446	6.8105	8.2606	7.3278	8.3109	7.8270	8.0795	
114.000	5.1319	4.4062	5.4098	6.0486	5.7231	5.8297	4.9832	6.1529	5.3696	6.1350	5.6891	5.9124	
116.000	3.8122	3.2605	4.0050	4.5194	4.2197	4.3245	3.6912	4.6322	3.9813	4.5777	4.1863	4.3779	
118.000	2.8714	2.4491	3.0030	3.4140	3.1488	3.2452	2.7702	3.5261	2.9888	3.4544	3.1190	3.2793	
120.000	2.1935	1.8676	2.2824	2.6096	2.3797	2.4640	2.1056	2.7138	2.2719	2.6369	2.3553	2.4878	

MONTHLY DENSITY (KG/M^3) AT 30 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	7.8321	8.1048	8.5465	9.2295	9.4494	9.5100	9.3451	8.8642	8.7369	8.3683	8.1780	8.0449	-5
72.000	5.8706	6.0848	6.4988	6.9987	7.1096	7.1164	6.9216	6.5464	6.5042	6.2657	6.1495	6.0867	
74.000	4.4012	4.5593	4.8418	5.2024	5.2944	5.2808	5.1533	4.8640	4.8470	4.6661	4.5809	4.5197	
76.000	3.2777	3.3924	3.5839	3.8412	3.9101	3.8861	3.8027	3.5837	3.5825	3.4472	3.3916	3.3393	
78.000	2.4238	2.5050	2.6339	2.8130	2.8635	2.8373	2.7822	2.6194	2.6262	2.5265	2.4959	2.4549	
80.000	1.7765	1.8340	1.9231	2.0444	2.0802	2.0562	2.0167	1.8979	1.9083	1.8371	1.8257	1.7977	
82.000	1.2943	1.3306	1.3939	1.4740	1.4985	1.4795	1.4486	1.3638	1.3747	1.3254	1.3270	1.3107	
84.000	9.3456	9.5665	10.0420	10.5580	10.7160	10.5810	10.3160	9.7195	9.8239	9.4962	9.5902	9.5265	-6
86.000	6.6979	6.8174	7.1889	7.5121	7.6089	7.5254	7.2982	6.8778	6.9782	6.7624	6.8909	6.9004	
88.000	4.7671	4.8176	5.1200	5.3174	5.3696	5.3282	5.1155	4.8332	4.9144	4.7908	4.9250	4.9851	
90.000	3.3728	3.3787	3.6283	3.7460	3.7693	3.7586	3.5699	3.3785	3.4485	3.3807	3.5022	3.5985	
92.000	2.3704	2.3503	2.5573	2.6259	2.6304	2.6394	2.4758	2.3462	2.4069	2.3750	2.4749	2.5755	
94.000	1.6626	1.6290	1.7909	1.8384	1.8325	1.8527	1.7152	1.6272	1.6795	1.6686	1.7442	1.8447	
96.000	1.1649	1.1266	1.2647	1.2875	1.2760	1.3010	1.1881	1.1279	1.1728	1.1736	1.2270	1.3203	
98.000	8.1761	7.7969	8.8985	9.0347	8.9008	9.1566	8.2534	7.8365	8.2201	8.2828	8.6302	9.4467	-7
100.000	5.7550	5.4091	6.2767	6.3623	6.2287	6.4653	5.7563	5.4629	5.7882	5.8708	6.0762	6.7636	
102.000	4.0618	3.7622	4.4328	4.4916	4.3704	4.5757	4.0310	3.8224	4.0946	4.1776	4.2793	4.8365	
104.000	2.8893	2.6382	3.1521	3.1962	3.0911	3.2616	2.8478	2.6969	2.9232	2.9983	3.0312	3.4724	
106.000	2.0742	1.8682	2.2583	2.2942	2.2064	2.3439	2.0331	1.9226	2.1093	2.1727	2.1624	2.5037	
108.000	1.5048	1.3384	1 6334	1.6640	1.5921	1.7003	1.4680	1.3859	1.5394	1.5912	1.5565	1.8169	
110.000	1.1042	.9709	1 1932	1.2199	1.1621	1.2459	1.0732	1.0116	1.1373	1.1784	1.1317	1.3275	
112.000	8.1982	7.1356	8.8122	9.0480	8.5859	9.2272	7.9438	7.4758	8.5047	8.8266	8.3197	9.7816	-8
114.000	6.1635	5.3178	6.5825	6.7912	6.4250	6.9115	5.9588	5.6004	6.4423	6.6987	6.1899	7.2725	
116.000	4.6925	4.0188	4.9783	5.1618	4.8716	5.2379	4.5281	4.2509	4.9417	5.1330	4.6645	5.4644	
118.000	3.6179	3.0794	3.8095	3.9708	3.7414	4.0161	3.4866	3.2765	3.8387	3.9846	3.5596	4.1483	
120.000	2.8239	2.3917	2.9515	3.0925	2.9103	3.1156	2.7183	2.5480	3.0178	3.1293	2.7514	3.1856	

MONTHLY DENSITY (KG/M^3) AT 45 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	7.0200	7.4169	8.0918	8.8889	9.7826	9.8282	9.8592	9.1423	8.4824	7.6526	7.1452	6.8601	-5
72.000	5.2046	5.6022	6.1136	6.7285	7.4369	7.7757	7.3600	6.7963	6.2930	5.7417	5.3962	5.1884	
74.000	3.9787	4.2039	4.5788	5.0577	5.6067	5.8567	5.4900	5.0536	4.7276	4.3111	4.0659	3.8931	
76.000	2.9819	3.1403	3.4120	3.7732	4.1856	4.3630	4.0519	3.7249	3.5198	3.2131	3.0499	2.9103	
78.000	2.2235	2.3333	2.5287	2.7925	3.0914	3.2054	2.9589	2.7222	2.5965	2.3767	2.2764	2.1674	
80.000	1.6484	1.7238	1.8639	2.0495	2.2573	2.3250	2.1367	1.9715	1.8943	1.7433	1.6895	1.6085	
82.000	1.2143	1.2649	1.3655	1.4908	1.6282	1.6614	1.5258	1.4147	1.3673	1.2681	1.2458	1.1890	
84.000	8.8898	9.2227	9.9484	10.7540	11.6090	11.7280	10.7810	10.0600	9.7686	9.1496	9.1274	8.7589	-6
86.000	6.4691	6.6789	7.2064	7.6946	8.1844	8.1751	7.5453	7.0908	6.9031	6.5549	6.6426	6.4300	
88.000	4.6799	4.8049	5.1920	5.4652	5.7122	5.6474	5.2353	4.9556	4.8391	4.6658	4.8014	4.7048	
90.000	3.3680	3.4342	3.7211	3.8563	3.9529	3.8696	3.6075	3.4370	3.3717	3.3049	3.4475	3.4313	
92.000	2.4083	2.4358	2.6497	2.7018	2.7125	2.6376	2.4683	2.3629	2.3343	2.3282	2.4555	2.4907	
94.000	1.7181	1.7206	1.8810	1.8876	1.8561	1.7962	1.6859	1.6180	1.6161	1.6393	1.7414	1.8048	
96.000	1.2239	1.2116	1.3323	1.3170	1.2692	1.2277	1.1516	1.1048	1.1205	1.1551	1.2305	1.3060	
98.000	8.7226	8.5212	9.4279	9.1976	8.7035	8.4377	7.8925	7.5442	7.8128	8.1668	8.6808	9.4476	-7
100.000	6.2270	5.9938	6.6733	6.4403	5.9992	5.8541	5.4358	5.1613	5.4837	5.8008	6.1227	6.8360	
102.000	4.4504	4.2149	4.7206	4.5202	4.1578	4.0926	3.7639	3.5403	3.8778	4.1385	4.3167	4.9408	
104.000	3.2001	2.9800	3.3551	3.1971	2.9138	2.9029	2.6337	2.4486	2.7745	2.9795	3.0591	3.5842	
106.000	2.3184	2.1215	2.3985	2.2821	2.0680	2.0873	1.8653	1.7118	2.0121	2.1674	2.1832	2.6120	
108.000	1.6946	1.5240	1.7281	1.6466	1.4885	1.5253	1.3386	1.2115	1.4793	1.5944	1.5722	1.9151	
110.000	1.2509	1.1060	1.2559	1.2017	1.0871	1.1308	.9743	.8696	1.1036	1.1870	1.1440	1.4140	
112.000	9.3297	8.1171	9.2191	8.8785	8.0580	8.5184	7.1918	6.3316	8.3478	8.9419	8.4202	10.5240	-8
114.000	7.0377	6.0308	6.8412	6.6441	6.0635	6.5086	5.3870	4.6821	6.4077	6.8216	6.2757	7.9033	
116.000	5.3707	4.5394	5.1369	5.0377	4.6312	5.0505	4.0935	3.5157	4.9853	5.2682	4.7393	5.9947	
118.000	4.1470	3.4611	3.9032	3.8693	3.5882	3.9707	3.1548	2.6803	3.9328	4.1186	3.6262	4.5936	
120.000	3.2394	2.6738	3.0023	3.0104	2.8188	3.1666	2.4642	2.0732	3.1411	3.2578	2.8113	3.5578	

MONTHLY DENSITY (KG/M^3) AT 60 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	5.2763	6.0837	7.1200	8.7440	10.2670	11.6830	11.7020	10.6540	8.1589	6.7653	5.6696	5.1192	-5
72.000	4.0127	4.5928	5.3500	6.6376	7.8342	8.8876	8.8784	8.0231	6.0556	5.0852	4.3106	3.9163	
74.000	3.0526	3.4691	4.0327	5.0229	5.9528	6.8007	6.6389	5.9426	4.5605	3.8275	3.2704	2.9778	
76.000	2.3155	2.6125	3.0262	3.7726	4.4704	5.1139	4.8951	4.3574	3.4010	2.8643	2.4755	2.2579	
78.000	1.7497	1.9605	2.2606	2.8101	3.3128	3.7683	3.5562	3.1628	2.5100	2.1302	1.8676	1.7057	
80.000	1.3158	1.4650	1.6795	2.0739	2.4189	2.7106	2.5442	2.2738	1.8292	1.5731	1.4029	1.2833	
82.000	9.8382	10.8910	12.4050	15.1540	17.3800	19.0060	17.9150	16.1830	13.1610	11.5310	10.4790	9.6051	-6
84.000	7.3111	8.0515	9.1045	10.9640	12.2860	12.9830	12.4260	11.4110	9.3445	8.3900	7.7793	7.1537	
86.000	5.3978	5.9154	6.6381	7.8547	8.5499	8.6585	8.4944	7.9701	6.5568	6.0622	5.7351	5.2985	
88.000	3.9578	4.3167	4.8052	5.5737	5.8622	5.6537	5.7317	5.5161	4.5486	4.3517	4.1958	3.9038	
90.000	2.8822	3.1272	3.4531	3.9201	3.9686	3.6372	3.8248	3.7838	3.1292	3.1061	3.0447	2.8685	
92.000	2.0886	2.2443	2.4582	2.7309	2.6547	2.3150	2.5261	2.5702	2.1345	2.2025	2.1870	2.0816	
94.000	1.4946	1.6003	1.7394	1.8927	1.7665	1.4741	1.6614	1.7356	1.4541	1.5584	1.5597	1.5094	
96.000	1.0685	1.1339	1.2231	1.3069	1.1731	.9443	1.0913	1.1667	.9911	1.1015	1.1049	1.0912	
98.000	7.6185	7.9933	8.5631	9.0147	7.8115	6.1310	7.1090	7.8266	6.7914	7.7955	7.7862	7.8759	-7
100.000	5.4221	5.6117	5.9722	6.2234	5.2325	4.0469	4.7643	5.2528	4.6864	5.5312	5.4663	5.6814	
102.000	3.8512	3.9221	4.1488	4.3007	3.5310	2.7204	3.1797	3.5288	3.2612	3.9333	3.8226	4.0922	
104.000	2.7444	2.7446	2.8863	2.9921	2.4151	1.8704	2.1506	2.3892	2.2988	2.8174	2.6792	2.9586	
106.000	1.9659	1.9273	2.0156	2.0997	1.6778	1.3169	1.4768	1.6343	1.6452	2.0357	1.8862	2.1495	
108.000	1.4182	1.3616	1.4160	1.4891	1.1853	.9486	1.0313	1.1328	1.1953	1.4855	1.3378	1.5723	
110.000	1.0321	.9699	1.0031	1.0685	.8523	.6991	.7328	.7968	.8829	1.0958	.9578	1.1590	
112.000	7.5850	6.9791	7.1758	7.7650	6.2356	5.2594	5.3003	5.6954	6.6207	8.1752	6.9348	8.6207	-8
114.000	5.6373	5.0825	5.1951	5.7194	4.6435	4.0397	3.9028	4.1401	5.0461	6.1725	5.0846	6.4758	
116.000	4.2402	3.7507	3.8103	4.2720	3.5178	3.1610	2.9230	3.0621	3.9034	4.7175	3.7885	4.9177	
118.000	3.2290	2.8062	2.8335	3.2353	2.7079	2.5207	2.2260	2.3027	3.0651	3.6497	2.8588	3.7755	
120.000	2.4899	2.1295	2.1368	2.4842	2.1172	2.0435	1.7223	1.7682	2.4394	2.8574	2.1808	2.9318	

MONTHLY DENSITY (KG/M^3) AT 75 N

ALT (KM)	J	F	M	A	M	J	J	A	S	O	N	D	
70.000	4.2820	4.7939	6.2895	8.1964	10.7860	12.9150	13.3230	11.4150	8.3330	5.8318	4.7911	4.3783	-5
72.000	3.2312	3.6809	4.7195	6.1822	8.2971	10.0010	10.2850	8.7514	6.2207	4.3593	3.6153	3.3313	
74.000	2.4972	2.7548	3.5981	4.7084	6.3362	7.7381	7.7645	6.4865	4.7049	3.2896	2.7566	2.5609	
76.000	1.9235	2.1083	2.7281	3.5555	4.7709	5.8594	5.7517	4.7446	3.5181	2.4694	2.0987	1.9632	
78.000	1.4755	1.5951	2.0560	2.6599	3.5331	4.3171	4.1689	3.4228	2.5970	1.8431	1.5940	1.4995	
80.000	1.1243	1.2043	1.5368	1.9676	2.5667	3.0750	2.9509	2.4376	1.8872	1.3660	1.2057	1.1391	
82.000	8.5012	9.0313	11.3860	14.3800	18.2570	21.0770	20.3590	17.1200	13.4900	10.0470	9.0717	8.5982	-6
84.000	6.3686	6.7171	8.3497	10.3750	12.7060	13.8650	13.6920	11.8760	9.4759	7.3311	6.7812	6.4432	
86.000	4.7265	4.9534	6.0597	7.3920	8.6532	8.7636	8.9801	8.1325	6.5583	5.3093	5.0321	4.7920	
88.000	3.4696	3.6158	4.3463	5.1995	5.7746	5.3447	5.7581	5.5065	4.4591	3.8154	3.7021	3.5344	
90.000	2.5211	2.6130	3.0827	3.6153	3.7870	3.1755	3.6223	3.6864	2.9998	2.7239	2.6992	2.5864	
92.000	1.8088	1.8640	2.1568	2.4830	2.4459	1.8560	2.2439	2.4417	1.9960	1.9294	1.9450	1.8741	
94.000	1.2874	1.3178	1.4952	1.6936	1.5689	1.0853	1.3817	1.6067	1.3247	1.3623	1.3898	1.3500	
96.000	9.0915	9.2297	10.2740	11.4910	10.0440	6.4184	8.5103	10.5350	8.7954	9.5967	9.8467	9.6721	-7
98.000	6.3921	6.4213	7.0190	7.7868	6.4606	3.8811	5.2801	6.9031	5.8776	6.7642	6.9306	6.9089	
100.000	4.4789	4.4419	4.7747	5.2814	4.1934	2.4116	3.3179	4.5369	3.9631	4.7753	4.8511	4.9259	
102.000	3.1324	3.0586	3.2389	3.5904	2.7535	1.5429	2.1167	2.9926	2.7018	3.3778	3.3788	3.5062	
104.000	2.1985	2.1000	2.2042	2.4608	1.8411	1.0204	1.3804	1.9968	1.8714	2.4056	2.3557	2.5047	
106.000	1.5537	1.4611	1.5103	1.7052	1.2559	.6974	.9216	1.3500	1.3199	1.7286	1.6493	1.7999	
108.000	1.1074	1.0199	1.0444	1.1965	.8751	.4916	.6306	.9280	.9481	1.2544	1.1626	1.3035	
110.000	7.9824	7.1947	7.3101	8.5161	6.2298	3.5683	4.4199	6.4886	6.9409	9.2074	8.2759	9.5287	-8
112.000	5.8218	5.1364	5.1846	6.1509	4.5277	2.6592	3.1711	4.6228	5.1722	6.8364	5.9579	7.0379	
114.000	4.3054	3.7202	3.7344	4.5132	3.3588	2.0324	2.3262	3.3543	3.9255	5.1411	4.3479	5.2602	
116.000	3.2277	2.7348	2.7321	3.3633	2.5403	1.5893	1.7429	2.4806	3.0293	3.9148	3.2184	3.9796	
118.000	2.4554	2.0425	2.0319	2.5460	1.9567	1.2702	1.3314	1.8664	2.3769	3.0200	2.4185	3.0493	
120.000	1.8936	1.5488	1.5351	1.9562	1.5330	1.0357	1.0356	1.4290	1.8927	2.3584	1.8443	2.3658	

END
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